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MEMORIAL OF LOREN B. MERRILL

CHARLES PALACHE.

Loren B. Merrill of Paris, Maine, died at his home on March 30, 1930 at the age of 77 years. The death of Mr. Merrill will bring a sense of great personal loss to a wide circle of friends who came to know him through his love of minerals. The writer of this appreciation first met Mr. Merrill in 1896. Then a stranger to eastern mineral localities, I went to Paris Hill one late September day and made my way to Mr. Merrill's house. I had seen in the Harvard Mineralogical Museum the tourmalines and associated minerals taken from Mt. Mica and presented as the Hamlin Collection. I wanted to see the deposit from which they had come and as Mr. Merrill then owned the mine on Mt. Mica, he was naturally the first person to seek. He was cordial in his greeting and next morning took me with him to the mine where he was working and turned me loose on the dump. I had a wonderful day for there was a wealth of minerals unfamiliar to me to be had for the taking, and the dump was at that faraway time not so well picked over by collectors as in later days. That was the first of many visits to Paris Hill and to Loren Merrill, sometimes with my class on a spring collecting trip; again for more serious collecting or purchase of specimens. I never failed to find him with something new or interesting in the way of minerals found in his ever active search. I like to remember him in his little shop behind his house where he learned to cut in the greatest perfection the beautiful tourmalines, quartzes and beryls he had dug from the Maine ledges. He was active at Mt. Mica from the very earliest period of its working as a tourmaline mine and after the dissolution of the first company organized by Mr. Hamlin of which he had been an employee, he became the owner. Single handed or with one or two helpers only he carried on the work for many years, his enthusiasm overcoming the ever increasing difficulties of operation as the zone of gem-pockets went deeper into the ledge. The cut on

the top of Mt. Mica and the great pile of waste taken from it will remain for many years the best monument to his tireless energy.

Another picture of Merrill vivid in my memory is of his coming once into the laboratory in Cambridge seeking information from us there as to the polishing of his gems. He had learned how to shape them to gem form but the final art of polishing the facets eluded him, and he thought to learn from our work in cutting and polishing prisms for optical study what he needed. We could tell him nothing of value. Nor do I know how or when he did learn to do the exquisite work which he later produced. But machines of his own design were perfected and he taught many of his friends and neighbors the beautiful art of gem cutting.

He lived among minerals in a very literal sense. His garden paths were bordered by quartz and brightly colored minerals from Mt. Mica. The stone wall bounding his drive was an outdoor museum of all the local minerals. His stable was littered with mica and feldspar and quartz and a hundred boxes had to be gone over to find the full count of his stock. In his cabinet were his choicest specimens, some of which he would never part with. And in his safe were his gems and gem stock—largely of his own finding. He never seemed so happy as when he had his finest pieces on the table and could tell the story to appreciative listeners of where and how each had been found. He kept in his possession for many years and to the end of his days a tourmaline crystal which he considered the finest he had ever found among the hundreds he took from the gem pockets of Mt. Mica. This crystal he had agreed to cut for the Harvard Collection and a large price was agreed upon for the gem and the work. But he could not bring himself to cut it and I have before me his last letter to me in which he asks to be freed from his engagement as he feared the crystal might be shattered if cut in so large a form as we had planned.

A more intimate relation with Mr. Merrill began in 1923. Harvard University had acquired some years before the lease of a tourmaline ledge on Noyes Mt. in Greenwood, Maine. I hoped to develop this ledge in such a way as to add to our scientific knowledge of these pegmatite deposits. Mr. Merrill, then more than 70 years of age, was engaged to do the actual work of opening the deposit. My student, K. K. Landes, was my representative on the ground, but I spent many days of that summer on the ledge. The mine was high up the mountain, 350 feet above the road up a steep

trail. I can never forget the sight of Merrill's gaunt, bent form toiling up the trail laden with drills, water, powder, or any of the necessary supplies for the work; sliding down at night burdened with specimens developed during the day; striking the drill hour after hour in the heat of the morning sun which beat into the shallow opening. Never did he seem to tire or lose his intense interest. After each blast he was the first to be down to see what might have been revealed. And when the work ended with very disappointing results as regards gems or specimens found, he still persisted in the belief that we had not reached the heart of the matter and later took over the lease in the hope of working it again for himself. This however he never did for he became actively interested in the development of quartz and pollucite properties for the General Electric Company and so continued till his death.

Self-taught in his mineral lore, he could teach us all much about minerals. He was a natural mechanic and made seemingly of iron and whipcord. The gems mined with his own hands and cut with the eye of an artist were far more to him than money. I count it a fortunate chance that made it possible for me to call this kindly, simple, sincere enthusiast, my friend.

THE HIDDENITE DEPOSIT IN ALEXANDER COUNTY, NORTH CAROLINA

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INTRODUCTION

In this magazine for August, 1927, S. C. Davidson gave a brief preliminary account of the geological relations of the hiddenite deposit. In the following pages are presented the results of the petrographic study of materials collected in 1926, made principally by Davidson but extended and verified by Goranson. To these have been added crystallographic data, in part based on Goranson's observations, in part on those of Mr. Berman and the senior author. The latter was able to study additional material through the kindness of Mr. B. S. Colburn of Asheville, N. C. This gentleman has assembled in a private museum at Asheville all the numerous specimens taken from the hiddenite mine when reopened in 1926 under the direction of his brother, W. B. Colburn. A careful examination of this interesting collection was made by Palache in 1930 and Mr. Colburn also supplied photographs of some of the matrix specimens of hiddenite and additional crystallographic material for study. We desire to express here our great indebtedness to the Messrs. Colburn for the many favors received at their hands.

The locality of the hiddenite mine has been variously designated at different times. It was first found about 50 years ago on the Warren Farm near Salem Church, Sharpe's Township, Alexander

Co. The name Stony Point later appears for the locality, taken from the nearest village. After the opening of what came to be known as the Emerald and Hiddenite Mine the name of the nearest post office and railroad station was changed to Hiddenite, and this name is still used. The mine is about a mile north of the station which is 15 miles northwest from Statesville.

Hiddenite seems to have been found at only one locality other than that of its original discovery and this was a vein within a short distance, never fully opened. Beryl, quartz and other of its associated minerals are found in many other localities in Alexander County in the near vicinity of the hiddenite mine.

DESCRIPTION OF THE COUNTRY ROCK

The rock of the Piedmont region in the vicinity of the deposit is a contorted and profoundly metamorphosed gneiss of Pre-Cambrian age. In hand specimens the grayish rock appears to consist of a fine granular aggregate of quartz, biotite, and garnet, intensely folded and crumpled. The banding is due to alignment of the biotite plates. Microscopically the gneiss consists of an irregular mosaic of quartz, plagioclase and biotite. Garnet, conspicuous in hand specimens, is absent in the thin sections studied. The quartz and plagioclase are intimately interlocked in anhedral grains. The plagioclase, usually easily recognized by the presence of albite twin lamellae, is a calcic andesine. The biotite occurs in ragged, strongly pleochroic plates approximately oriented with their longer diameters in a parallel direction. In all the sections a considerable amount of rounded zircon grains were present, usually enclosed in biotite and giving strong pleochroic halos. Apatite occurs mainly in minute prismatic shapes or rounded cross sections. In one section ragged grains of augite are present, altering about their borders to a green hornblende. The average grain size of the major constituents is about 0.15 millimeters. A rough estimate of the proportion of minerals in thin sections is as follows: Quartz 50 per cent, andesine 15 per cent, biotite 30 per cent, zircon, garnet and apatite 5 per cent. Some pyrite is scattered through the rock near the pegmatites and has been undoubtedly introduced during their formation.

The present mineralogical constitution of the rock indicates that it was initially an argillaceous sandstone, regionally metamorphosed at considerable depth permitting recrystallization and re-

orientation of mineral grains. The quartz and plagioclase merely recrystallized while the argillaceous material formed mainly biotite and garnet. In brief, the chief evidences for a sedimentary origin of the metamorphosed rock are the high content of quartz and the high content of rounded zircon grains.

DESCRIPTION OF THE PEGMATITES

Observations in the field and the study of hand specimens permit three later stages of mineralization to be distinguished. Prior to at least a portion of the folding, the gneiss was invaded by solutions which resulted in the development of numerous lit-par-lit injections of quartz-feldspar pegmatite. These range from paper-thin veinlets to dikes upwards of a foot in width; in numerous places the feldspar individuals or the dikes as a whole are granulated or drawn out into augen shapes by the folding. Later than this lit-par-lit injection were two periods of pegmatite formation in both of which hiddenite was deposited. The minerals of these three stages are shown in the following table; and will be described in succeeding pages.

LIT-PAR-LIT PEGMATITE	HIDDENITE PEGMATITE	HIDDENITE "CAVITIES"
Quartz	Quartz	Quartz
Andesine	Andesine	Amethyst
Orthoclase	Microcline	Albite
Microcline	Hiddenite	Adularia
Bronzite	Tourmaline	Hiddenite
Tourmaline	Garnet	Holmquistite
Apatite	Dumortierite	Beryl
Pyrite	Sillimanite	Tourmaline
	Zircon	Garnet
	Biotite	Muscovite
	Sericite	Nontronite
	Rutile	Rutile
	Apatite	Apatite
	Pyrite	Monazite
	Calcite	Pyrite
		Arsenopyrite
		Calcite
		Ankerite
		Siderite
		Aragonite

LIT-PAR-LIT PEGMATITE STAGE. These stringers and lenses are narrow, averaging half an inch in width and were injected along

the foliation planes and cross fractures in the gneiss. The earliest injection evidently preceded a large part of the metamorphism of the country rock. In consequence these stringers appear now extremely contorted, resembling the folded migmatites described by Sederholm in Finland.¹ The main constituents of these stringers are fine-grained quartz and andesine with a little orthoclase forming a symplectite texture with the plagioclase. Coarse grained dikes up to a foot in width occur mainly in the fractures cross-cutting the gneissic structure. Microscopically they show coarse grains of quartz, andesine and microcline and around the borders of the large grains, small irregular grains of the same minerals. In one hand specimen a coarse-grained cross-cutting stringer is faulted, the fault plane later intruded by a stringer identical in mineralogical content with the former.

A third type of pegmatite is composed mainly of andesine and bronzite in fairly coarse grains. The plagioclase has a brownish color and the associated country rock is much higher in ferromagnesian minerals than the usual type. A little black tourmaline and orthoclase is also present.

Usually there is a little apatite associated with the stringers and often a little biotite. Frequently biotite is concentrated slightly along the walls of the stringers. With the exception of the last described stage the mineralogy of the stringers is strikingly similar although a considerable time interval may have elapsed between the first and later stages. The coarse-grained cross-cutting dikes formed near the end of the metamorphism and consequently suffered little deformation. The first impregnations suffered intense deformation culminating in the entire recrystallization of quartz and plagioclase. The later types show only relatively minor stress effects such as anomalous extinction of the mineral grains, bending of the albite twin lamellae and crushing about the borders of the coarse-grained constituents. Mineralogically the chief difference in the later phases is the increased amount of orthoclase and the formation of microcline and considerable pyrite.

A characteristic feature of these stringers is the presence of symplectite, a peculiar vermicular intergrowth of plagioclase and orthoclase. The orthoclase occurs in irregular worm-like forms in the plagioclase, the texture usually confined to the medium sized

¹ Sederholm, H. On Migmatites and Associated Pre-Cambrian Rocks of South-western Finland. *Helsingfors*, 1923.

or large grains. The microscopic evidence indicates the texture is due to replacement of the plagioclase by orthoclase and gradations may be traced from plagioclase grains almost free from orthoclase, to orthoclase grains containing corroded islands of andesine. The andesine remnants contain vermicular interpenetrations of orthoclase optically continuous with the outer part. A few grains of plagioclase show blebs of orthoclase arranged along the cleavage planes.

THE HIDDENITE PEGMATITE STAGE. The hiddenite pegmatites mainly parallel the gneissose structure of the country rock and occur in lens-like or dike-like bodies, the latter continuous for some distance. The average width of the bodies is around three inches. The texture of these bodies varies from fine to relatively coarse, the larger crystals generally surrounded by an enclosing hull of sugary, grained material. These bodies have sharp contacts towards the country rock and along the walls is usually a considerable concentration of biotite. Wall-rock alteration is on the whole lacking, except for a few large grains of apatite near the contacts with the country rock which may be due to metasomatic processes.

Microscopically the coarse-grained feldspar resolves into microcline with its characteristic grid structure surrounded on its borders by a fine-grained mosaic of microcline and quartz. The larger grains of microcline have numerous inclusions of small oval-shaped grains of plagioclase oriented with their longest axes in a definite parallel direction. The intergrowth may be termed a "Guttate Perthite," similar to that described by Barth² in the Adirondack feldspars. The average size of the blebs is .008 millimeters in width and .060 millimeters in length, the larger blebs confined to the border of the grains and decreasing in size towards the centre but increasing in numbers. The plane of the long axis of the blebs appears to be in the azimuth of the B-vibration direction of the microcline and the blebs are thus probably localized along the intersection of the (010) and (001) cleavages. The smaller surrounding grains of microcline are entirely free from these inclusions. The large grains of microcline show strain shadows.

Quartz is present in a moderate amount in the pegmatites, in large grains and minute fragments about the borders of the larger grains with microcline. The large grains of quartz show strain

² Barth, Tom F. W. Mineralogy of the Adirondack Feldspars. *Am. Mineral.*, Vol. 15, 1930, p. 130.

effects while the smaller appear to be unstressed. The quartz does not tend to develop crystallographic boundaries.

Andesine ($\text{Ab}_{60}\text{An}_{40}$) is present in subordinate amounts, in large and small grains. The large grains especially show decided strain shadows. The grain boundaries are rounded and suggest corrosion by the other constituents.

Brownish red garnet, of the variety spessartite, occurs in slightly distorted rhombic dodecahedrons. Their average cross section is about one inch. Poikilitically included in the garnets are a variety of minerals, quartz, green and blue tourmaline, dumortierite, microcline, sillimanite, biotite with included zircons and chlorite, all in small quantity. The dumortierite occurs in a bundle of finely fibrous needles with its diagnostic pleochroism—cobalt blue along the length of the fibers. The biotite inclusions are partly altered to chlorite.

Hiddenite occurs in these pegmatites in moderate amounts embedded in microcline or quartz. It has an olive green color and is prismatic in habit with excellent cleavages at about 90° . The crystals reach a length of about one-quarter inch. In thin section the hiddenite appears partly altered along its cleavages to chlorite and replaced around its borders by calcite. Small elongated crystals of black rutile are often included in the hiddenite.

Blue, green and black tourmaline occur, the blue and light green found only in small amounts in thin section. The blue tourmaline is present as inclusions in garnet and as small rounded grains in quartz. The light green variety has a similar occurrence. Well-shaped crystals of black tourmaline are present in hand specimens; the prisms are striated and truncated by steep rhombohedral faces. The refractive indices are much lower than those of schorlite ($\omega = 1.652$). It is probably a magnesium tourmaline with very little iron. The black tourmaline appears to cut across crystals of hiddenite.

Biotite occurs as concentrations along the walls of the pegmatite; as inclusions in garnet, and as flakes in the pegmatite. Rounded zircon grains are often present in the flakes resembling those in the biotite found in the country rock. Thus the indications are that all the biotite associated with the pegmatites has been derived from the country rock and exists as unreplaced residuals of the latter.

Some pyrite and calcite are present in the pegmatite, appearing

to fill either interstitial spaces or to replace some of the pegmatite minerals. Both may thus belong to the later cavity mineralization when they were deposited abundantly.

HIDDENITE "CAVITIES." From the mineralogical point of view the greatest interest in this deposit surrounds the "cavities" or pockets which were found in great number. These vary in size from minute druses to openings several feet in diameter. They vary widely in mineral contents but most of them contain either hiddenite or beryl or both. They are generally exceedingly sharply defined against the enclosing gneiss, occupying shear planes transverse to the foliation, the contained minerals being implanted directly upon the walls. In fact these cavities remind one very strongly of the Alpine clefts in form, structure and the habit and nature of the contained minerals. Some are however less sharply delineated and are surrounded by zones of bleached or altered gneiss; here it is quite clear that solutions have been active and these cavities may well be the result of destructive attack on parts of earlier formed pegmatites. If so, there was later a renewal of deposition in them for they are lined with free-standing crystals of a variety of minerals.

It is these cavities that have yielded all the most interesting crystallized minerals for which the deposit is well known. In the following pages these minerals will be described as found in our specimens, with only casual attention to earlier descriptions.

Quartz. The most abundant mineral in these cavities is quartz, which very often forms the first coating of the walls, other minerals being implanted upon it. The form may be simple or of the utmost complexity as shown in the figures in *Dana's System*, page 185, which are derived from the descriptions of Von Rath (11). In the Colburn collection are several hundred small crystals obtained from the recent working. The vast majority are quite simple in form. A number however show trapezohedral forms and several show rounded etch faces close to the basal pinacoid in position as shown in figures by Hidden (4) and Miers (13). These have not been studied in detail. In the crystals in our possession there are no unusual forms but a few show delicate hair-fine inclusions of rutile. It was from one of these cavities of unusual size, found at the beginning of the mining here, that Hidden found the finest crystals of emerald, and hundreds of quartz crystals of great beauty with large liquid inclusions. The largest crystal weighed about 25

pounds. The largest "water-bubble" was some $2\frac{1}{2}$ inches in length. Hidden (2) gives a vivid account of the extraction of these crystals from the red clay which quite filled the pocket; and of the total destruction of the whole find while still exposed near the mine when the chill of a frosty night caused them to explode to a mass of shapeless fragments by the expansion of the frozen liquid inclusions. The same writer (14) recorded the interesting observations that the complexity of the form was greater when the number of crystals in the cavity was small and that the prevailing form when hiddenite was present was the steep rhombohedron (3031).

Amethyst. In a few narrow crevices the quartz shows two or more generations. The earlier crystals are clear and colorless, of a slender habit. Many of them have been etched about the summits to produce a flattened surface upon which are implanted a later

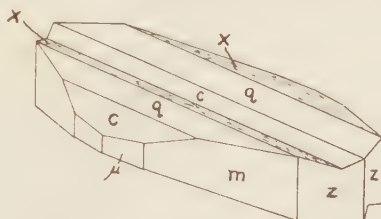


FIG. 1. Adularia, Hiddenite, N. C.

parallel growth of faintly amethystine quartz. As this quartz has a stouter habit the groups suggest a "scepter-quartz" on a very small scale. Occasionally the second generation shows the same etching faces and a third generation of striated crystals deposited upon their tips giving a curious steeple-shaped summit to the whole.

Feldspars. Albite was found as distinct crystals and in crystalline masses surrounding some vugs. The crystals are clear or milky, twinned on the albite law, and show the common forms and habit of this mineral.

Orthoclase in the habit of adularia was found in isolated crystals and twin groups attached to quartz in a few pockets.

The crystals are unusual both in habit and in the presence of some of the rarer forms reported on adularia. The measurements established the presence of the following forms: $c(001)$, $b(010)$, $a(100)$, $\zeta(210)$, $\mu(310)$, $m(110)$, $z(130)$, $\Delta(501)$, $q(203)$, $x(101)$, $n(021)$, $e(111)$ and $o(\bar{1}11)$. Of these forms a , ζ , μ , Δ , and e are extremely rare on feldspars even of the adularia variety. Figure 1.

shows the curious tabular habit of most of the simple crystals with deeply grooved surface; these tables are often attached by an edge. The second figure shows a less typical combination for the locality. On most crystals, faces like *e* and *n* are represented only by rounded surfaces of solution in striking contrast to which is the brilliancy of the prism zone faces.

The determination of the uncommon forms is based on the following measurements:

		MEASURED		CALCULATED		NO. OF FACES
		φ	ρ	φ	ρ	
ζ	210	73° 49'	90° 00'	73° 31'	90° 00'	1
μ	310	78 32	90 00	78 44	90 00	5
Δ	501	90 00	79 45	90 00	79 06	2
<i>e</i>	111	68 39	56 50	68 44	56 52	1

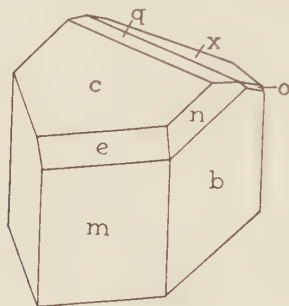


FIG. 2. Adularia.

Most of the adularia crystals are, however, complexly twinned. The twinning is commonly on the Baveno law and is repeated, as is so commonly the case with the Swiss adularia, to develop fourlings; the axis of elongation of the group is the *a* axis and the group is a square prism bounded by four faces of the basal pinacoid. The rounding of the terminal faces of these twin groups was so pronounced that it proved impossible to measure them but their nature was easily established. Regular fourlings of the type described were not so common however as pairs or triplets, all twinned on the Baveno law and with every sort of irregularity of mutual development. The glassy lustre of these crystals, the brilliance of the prism-zone faces when visible, and the variety of habit united to give them an appearance quite unlike any feldspar known to the writers.



PLATE I. Hiddenite, North Carolina.



PLATE II. Hiddenite, North Carolina.



PLATE III. Hiddenite. North Carolina.

Hiddenite. In the cavities hiddenite occurs in a great variety of habits. The commonest type, characteristic of all the earlier mined gem crystals is prismatic, with a square or more or less octagonal cross section. Such crystals are deeply etched on every surface, the terminal faces especially being reduced to uneven curved surfaces. Such crystals are illustrated in *Dana's System*, p. 367, taken from Hidden (8). The colored illustration on Plate V of *Kunz Gems of North America* is also of this type. This crystal, now in the Collection of Harvard University, is, like many of the gem quality, twinned on the orthopinacoid. In Mr. Colburn's operation of the quarry, but one cavity was found containing gem material. In it were some 20 good-sized crystals of good green color but not for the most part clear enough for cutting. In addition were many slivers and last remnants of solution which

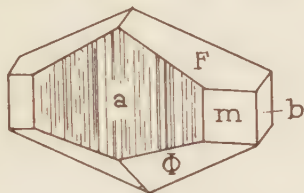


FIG. 3. Hiddenite, Hiddenite, N. C.

take the form of slender spicules or needles. Most of the cavities opened in 1926 where hiddenite occurred were sharply angular or pipe-like with attached crystals standing directly on the wall rock. The photographs reproduced herewith in Plates I-III show such cavities and their hiddenite crystals. These are flattened plates parallel to the orthopinacoid (100), are not twinned for the most part, and are dark green in color. They are always coated with gray nontronite which readily scales off showing sometimes very rough, sometimes smooth but dull faces beneath.

A modification of this habit is shown in figure 3. The prism planes are much reduced, pyramids and clinodome making the terminations. The greatest dimension of such crystals is in the direction of the *b* axis. A marked feature of both these types is the deeply grooved striation of the orthopinacoid due to oscillatory combination with the prism. This shows particularly well in the photograph, Plate III.

In a few cavities were found several small hiddenites of clear

green color whose general proportions are shown in figure 4. In these the prism zone was quite unattacked by etching agents, the faces being brilliantly reflecting and not striated. Most of the terminal planes, however, were dull but by attaching glass plates with

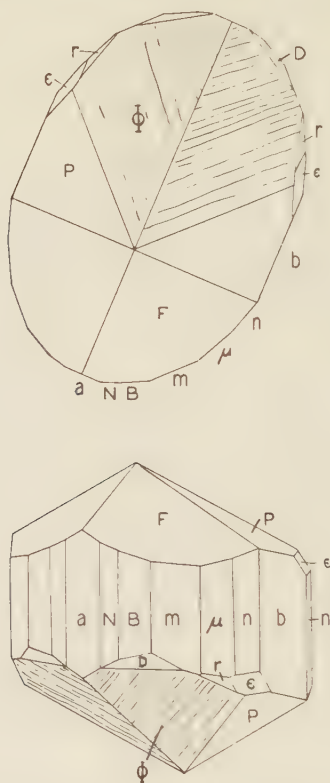


FIG. 4. Hiddenite, North Carolina.

glycerine, measurements were obtained sufficiently accurate to permit their identification. The form ϕ was deeply striated in direction of the intersection with p . The forms determined, most of them shown in the drawing, were as follows:

$a(100)$	$\mu(120)$	$\phi(\bar{3}12)$
$b(010)$	$n(130)$	$D(\bar{4}21)$
$N(310)$	$z(150)$	$r(221)$
$B(210)$	$F(011)$	$\epsilon(241)$
$m(110)$	$p(\bar{1}11)$	$t(\bar{4}81)$

Of these forms, the two prisms $N(310)$ and $B(210)$ are new to spodumene. They were found repeatedly and gave faultless signals on the goniometer.

MEASURED	CALCULATED
ϕ	ϕ
(310) $70^{\circ} 38'$ Av. of 6	$70^{\circ} 37'$
(210) $62^{\circ} 08'$ Av. of 3	$62^{\circ} 10'$

It is worthy of remark that the crystal constants of spodumene rest upon most unsatisfactory observations. The axial ratio of



FIG. 5. Hiddenite, North Carolina.

Dana's System is based on contact measurements; that used in Goldschmidt, Winkletabellen and Atlas, is taken from Vom Rath (10) who had to attach glass plates to crystal faces in order to secure readings. We examined hundreds of crystals of hiddenite in this research in the hope of finding any with satisfactory terminal faces but in no case successfully. Such readings as were obtained agreed fairly well with the angular values based on Vom Rath's axes.

Another extreme type of habit is shown in figure 5. which is a thin plate parallel to the orthopinacoid and twinned on that plane so that it presents perfect orthorhombic symmetry.

Holmquistite. This rare lithium-amphibole was first described by Osann³ from the Island of Utö in Sweden. It is found in a metamorphic schist near the contact of a lithium pegmatite. In the Hiddenite Mine it was found in and around a single cavity, notable for its considerable content of gem hiddenite. In the gneiss it is visible as a bluish band amidst the feldspathic areas and in thin section appears as ragged grains and fibres replacing the original quartz and feldspar. In one fragment of the cavity lining, the holmquistite was found in fairly stout prisms of measureable size and quality. They are bounded by the prism (110) and orthopinacoid (100). The prism angle is $54^{\circ}39'$, the result of two independent and satisfactory readings. The prism angle measured by Osann on Utö holmquistite is given as $55^{\circ}48'$. This was probably made on a cleavage fragment and the divergence of the two values may be due to poor readings.

The optical properties as determined by Goranson are as follows: $\alpha = 1.625$; $\beta = 1.645$; $\gamma = 1.654$.

Pleochroism, X = light yellow; Y = violet; Z = purplish violet. $Z \wedge c$ = parallel or almost so. Dispersion weak. $\rho > v$. $2V = 51^{\circ}$ (determined on the Fedorow stage).

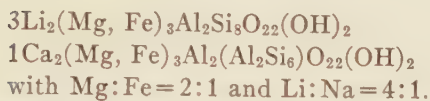
Material for analysis was secured by crushing some of the bands richest in holmquistite and concentrating the mineral by magnet and heavy solution. It was believed that the final sample obtained still contained about 5 per cent of dark inclusions, probably magnetite. The specific gravity of the powder is 3.111, determined by the pycnometer. The following analysis (2) was made by Earl V. Shannon in the laboratory of the U. S. National Museum. With it for comparison is that of Osann (1).

Holmquistite from the North Carolina locality is composed largely of the lithia member of the amphibole group⁴ and a minor amount of a deficient silica member commonly found in basic rocks.⁵ The formula deduced from the analysis is:

³ Osann, A. Ueber Holmquistit, einen Lithionglaucophan von der Insel Utö, *Sitzb. der Heidelberger Akad. Wiss.*, 1913, Abh. 23, 1-16.

⁴ This member is the lithia equivalent of the glaucophane member proposed by W. Kunitz, *Neues Jahrb., Beil. Bd. LX, Abt. A*, 1929, S. 171-250.

⁵ Priv. communication. H. Berman, A study of the amphiboles not yet completed indicates the presence of this type of amphibole in the more basic rocks.



In general the interpretation here presented fits the analysis fairly well. The low value for the calculated water may be ac-

ANALYSES OF HOLMQUISTITITE

	1 PER CENT	2 PER CENT	3 MOL. RATIOS		4 FOUND	5 CALCU- LATED	6 PER CENT	
SiO ₂	60.45	55.48	.9201	Si	7.4	7.5	56.13	SiO ₂
TiO ₂	trace	.64	.0080					
Al ₂ O ₃	7.70	14.64	.1432					
				Al	2.5	2.5	15.86	Al ₂ O ₃
Fe ₂ O ₃	9.68	1.80	.0113					
FeO	4.38	10.36	.1442					
MnO	—	trace		Mg	3.0	3.0	18.92	{ MgO FeO
MgO	12.12	9.40	.2331					
CaO	—	1.32	.0235	Ca	0.2	0.5	3.48	CaO
Na ₂ O	1.12	.66	.0106	Na	0.3	1.5	3.38	{ Na ₂ O Li ₂ O
K ₂ O	0.54	.74	.0079					
Li ₂ O	2.13	2.40	.0803	Li	1.3			
H ₂ O—	0.09							
H ₂ O+	2.28	3.16*	.1754	H	2.8	2.0	2.23	H ₂ O
F	0.43	trace						
Sum	100.92	100.60					100.00	
less								
O=F	0.18							
	100.74							

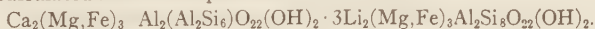
1. Analysis of Holmquistite from Utö, Sweden. Osann, analyst.

2. Analysis of Holmquistite from North Carolina. E. V. Shannon, analyst.

3. Molecular ratios of Column 2.

4. The number of cations present for 24 oxygen atoms. For method of computation see H. Berman, *Am. Min.*, 14, 11, 1929, p. 389.

5. Calculated atomic composition from formula:



6. Percentage composition calculated from column 5.

* The sample was insufficient to make a direct determination of water so that this constituent had to be taken by loss on ignition corrected for oxidation of ferrous iron. The fluorine likewise could not be determined, but judged from the qualitative test it is not present in important amount. E. V. Shannon.

counted for by the fact that insufficient material for a direct determination was not available. (See note following analysis).

The analysis of holmquistite from Utö, treated in the same manner as the North Carolina analysis yielded the formula $\text{Li}_2\text{Mg}_3\text{Al}_2\text{Si}_3\text{O}_{22}(\text{OH}, \text{F})_2$ which is the same as the North Carolina formula with no deficient silica member.

Beryl. This is, next to quartz, the most widespread mineral of the North Carolina pegmatites. It is generally pale blue-green or blue but at Hiddenite some of the crystals found were so deep a green as to be properly termed emerald. Here were found, very early in the working of the mine the two crystals now in the American Museum of Natural History which are well illustrated in Kunz, *Gems of North America*. The larger was $8\frac{1}{2}$ inches long and slender. The green coloring is confined to a deeply pigmented superficial layer. Like most of the larger crystals of beryl found in the region, these are of simple prismatic form with basal termination. Smaller crystals are exceedingly complex. Hidden and Washington (14) figured such a one and our figure 6 shows nearly the same combination but more complex, drawn with the actual development of the numerous faces. The forms shown are: $c(0001)$, $m(10\bar{1}0)$, $a(11\bar{2}0)$, $p(10\bar{1}1)$, $n(20\bar{2}1)$, $d(33\bar{6}4)$, $s(11\bar{2}1)$, $v(51\bar{6}1)$, $n(31\bar{4}1)$, $v(21\bar{3}1)$. This crystal was attached to the wall of a tiny pocket and is about $\frac{1}{2}$ inch in length. It is pale green in color. Other crystals in our collection show deep solution figures especially on the prism planes, the lenticular pits horizontally placed and so closely spaced as to entirely destroy the original surface. Other crystals show solution cracks filled with silver-white plates of muscovite. Part of the surface of the crystals is covered by small plates of muscovite and a fine greyish chloritic mineral. Calcite, quartz and pyrite crystals have grown on the beryl crystals. A few crystals altered entirely to fine-grained mica are in the collection.

Tourmaline. In the cavities tourmaline is found occasionally in black crystals, brown in thin section. There is no indication that lithium entered into their composition to any extent. They are slender attached needles with simple rhombohedral terminations at the free end.

Garnet. Garnet is rare in the cavities. It is a honey-yellow spessartite variety in small, poorly developed crystals.

Muscovite. Muscovite is generally present, often abundant and

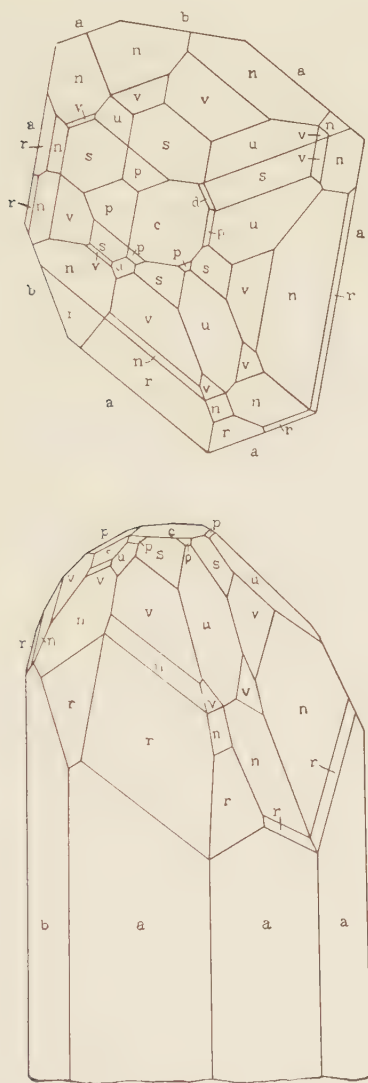


FIG. 6. Beryl, Hiddenite, N. C.

well crystallized. The crystals are often attached edgewise to the cavity and reach an inch or more in diameter. The commonest variety is a silvery mica with dusty bronzy exterior. The crystals are very thin basal plates with sharp hexagonal outline. Clarke (16)

has analyzed this muscovite and finds it a normal one. In one cavity the muscovite is light green in color and bears on its surface tiny crystals of rutile, apatite, and monazite.

Nontronite. Under this name may be described the coatings and alteration products which are often found in the cavities especially associated with hiddenite. Crystals of this substance rarely failed to show at least part of their surface coated with a dark green film or crust, beneath which the faces were always rough or etched. It may be removed with more or less ease, sometimes scaling off in millimeter thick crusts but is clearly a product of alteration. In some cases the whole crystal has been altered and complete pseudomorphs are found. This material has been called hisingerite in previous descriptions as by Clarke (16). Optically it agrees best with nontronite. No special study was made by us of this material.

Rutile. This is a mineral of widespread occurrence in the Hiddenite Mine pockets and is remarkable for the brilliance and beauty of its crystals as well as for an extraordinary range of habit. The majority of the crystals are slender needles, deeply furrowed in the prism zone, with simple terminations. These are untwinned, reach an inch or more in length, and are always attached to the cavity walls or to earlier minerals. Twin groups of an infinite variety are also to be seen, twinned on both laws, twin plane $e(101)$ or $v(301)$, both sometimes present in the same group. Vom Rath (10) figures a simple contact twin on v . The complexity of form is notable and the abundance of crystals with large development of the base is unusual. In the same hand specimen may be seen crystals of slender habit and others with prisms reduced to mere lines so the crystals are pyramidal; others are flattened parallel to a pair of prism faces so that they have exactly the appearance of thin brookite crystals. Again the network of twinned needles takes on the sagenite form. Hair-fine needles are included in quartz not rarely. The forms observed by us in a very incomplete study of these interesting crystals were as follows: Known forms: $c(001)$, $a(100)$, $m(110)$, $x(410)$, $h(210)$, $r(320)$, $e(101)$, $s(111)$, $E(117)$, $\alpha(227)$, $\beta(112)$, $Z(321)$, and $t(313)$, and the new forms $D(118)$, $F(115)$, $H(229)$, and $L(131)$.

The three forms D , F , and H were all found on the twin crystal shown in figure 7. It will be noted that these new forms are part of a highly differentiated zone between c and s which contains also F , α , and β . Compare with this figure that of Hidden and Wash-

ington (14) reproduced in *Dana's System*, p. 237. The form *L* was found on every crystal measured and is dominant on the type shown in figure 8, equant with *z* in figure 9.

	Calculated		Measured		No. of faces
	ϕ	ρ	ϕ	ρ	
<i>D</i> (118)	45°00'	6°30'	45°00'	6°38'	4
<i>F</i> (115)	45 00	10 19	45 00	10 16	2
<i>H</i> (229)	45 00	11 27	45 00	11 25	2
<i>L</i> (311)	18 26	63 51	18 26	63 51	7

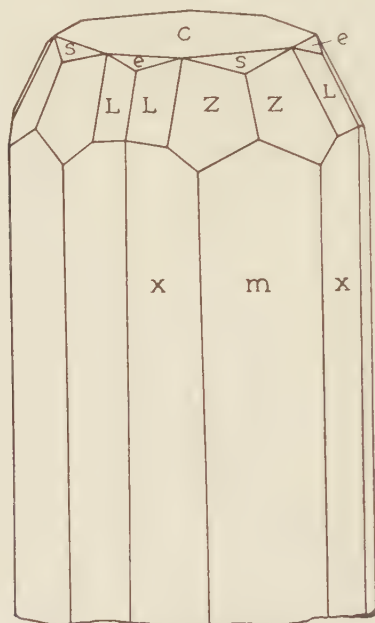


FIG. 9. Rutile, Hiddenite, N. C.

Monazite. Monazite is not rare in North Carolina pegmatites and has been frequently described. None of the published figures, however, actually refer to specimens from the Hiddenite Mine. It was found in our specimens in tiny, clear, honey-yellow crystals embedded in albite or calcite, or attached to cavity walls. The forms identified are shown in figure 10: *a*(100), *b*(010), *c*(001), *e*(011), ω (101), *n*(111), *v*($\bar{1}11$), *s*(121), and *o*($\bar{1}21$). The habit is either as shown in figure 10 or prismatic parallel to the edge of the pyramid $\bar{1}11$.

Apatite. Apatite is a very minor constituent of these cavities. Crystals of dull greenish white color and simple form were observed on one cavity wall. Hidden and Washington (14) published a figure reproduced in *Dana's System*, pp. 763 and 764, of a very complex apatite crystal. In one of our vug specimens minute water clear crystals were seen implanted on green muscovite which proved when measured to be almost identical with the published figure.

Pyrite. Pyrite in brilliant cubeoctahedrons is widely distributed in the cavities. It is seen implanted on rutile, quartz, beryl, hiddenite and muscovite. It offers no points of particular interest. To some extent, it has invaded the wall rock in granular masses.

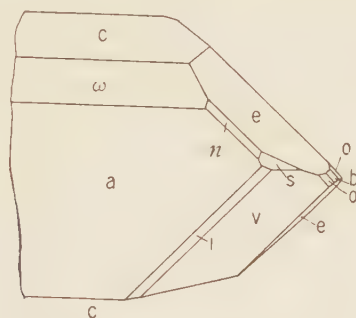


FIG. 10. Monazite, Hiddenite, N. C.

Arsenopyrite. Arsenopyrite is a rare constituent, first found by dissolving from a few cavities the calcite filling. The minute, perfect, and very brilliant crystals, having been completely embedded in calcite, are doubly terminated. They show the complex development of figure 11 the forms present being: $m(110)$, $c(101)$, $\rho(015)$, $q(013)$, $s(012)$, $l(011)$, $v(212)$, $o(112)$, $A(532)$ and $B(514)$. It is interesting to note that the last three forms o , A , and B have also been found on arsenopyrite formed in calcite at Franklin, N. J. They were first reported by Palache⁶ but not figured. The present figure might perfectly well serve for the Franklin crystals.

Carbonates. Three types of carbonate are present, calcite, ankerite, and siderite. Of the three, calcite is the most abundant and may be divided in age relationship into two types, optically into two, and crystallographically into three. The earliest formed cal-

⁶ Palache, Charles. Contribution to the Mineralogy of Franklin Furnace, N. J., *Am. Jour. Sci.*, 29, 1910, 177.

cite is in flattened rhomb-shaped crystals grouped in fan-like aggregates. It has a dull white color and its indices are higher than ordinary calcite ($\omega=1.667$). It reacts as normal calcite with cold hydrochloric acid. The later calcite forms in two crystal types which agree optically ($\omega=1.658$), one in hexagonal tablet-like individuals showing only the forms $c(0001)$ and $m(10\bar{1}0)$; the third type is in normal unit rhombohedrons. The ankerite ($\omega=$

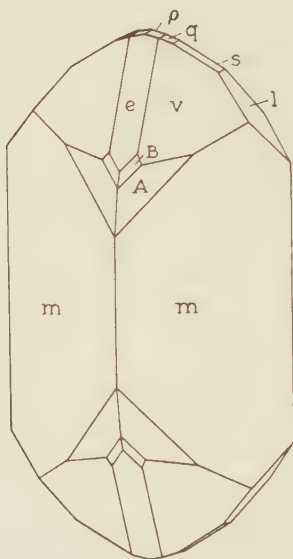


FIG. 11. Arsenopyrite, Hiddenite, N. C.

1.703) is in iron-oxide-coated rhombohedral crystals associated with the flat rhomb calcite, the latter usually growing over the ankerite crystals. Dolomite, early reported from the hiddenite cavities, is probably ankerite. A crystal of clean-cut rhombohedral form showing base and twin striae parallel to (0001) and to $(01\bar{1}2)$ was tested and gave an index ($\omega=1.702$) too high for dolomite.

Siderite. Siderite was found on one specimen in the form of yellow, rough rhombohedrons and crusts of reddish color. Both were late formations in cavities and were identified by much higher index of refraction.

Aragonite. White needles of aragonite were found in one or two cavities. The crystals could not be measured.

GENESIS

From a study of the hand specimens a tentative genetic history is proposed.

1. Metamorphism of the argillaceous sandstone.
2. Injection of the first migmatitic lit-par-lit stringers.
3. Renewed metamorphism followed by folding and recrystallization of the stringers.
4. Shearing of the country rock with the formation of transverse fractures.
5. Injection of the later stages of lit-par-lit stringers, followed by some movement.
6. Formation of the pegmatitic stringers along the foliation planes of the rock.
7. Slight shearing causing the separation of former incipient cross fractures.
8. Formation of the vug and cavity minerals.

The paragenetic sequence in the pegmatites is not definite. A small quantity of andesine followed by microcline and quartz was first to crystallize. Garnet, hiddenite, and tourmaline then followed with a later formation of quartz in vein-like bodies. The entire pegmatite was then subjected to slight movement resulting in granulation about the borders of the larger grains, especially microcline and quartz. The garnet was slightly distorted, the hiddenite and tourmaline show very little strain effects. The remaining pegmatite minerals are present in inconsequential amounts and their sequence is not evident. The formation of the vugs in the pegmatites then occurred through some change in the parent source; solution occurring instead of deposition. The highly irregular shape of the cavities supports this mode of origin of the cavities. Pyrite and calcite were probably introduced during the cavity stages.

Following the pegmatites, the mineralization of the vugs and openings took place. A more definite sequence was ascertained as here the minerals often grow on one another. The following sequence appeared universal in the cavities: quartz, hiddenite and beryl, mica, albite, siderite and flat rhomb calcite, quartz, monazite and rutile, adularia, pyrite, calcite, followed by corrosion of practically all the minerals and some oxidation of pyrite to limonite.

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TWO PHOSPHATES FROM DEHRN;¹ DEHRNITE AND CRANDALLITE

ESPER S. LARSEN, *Harvard University,*
and

EARL V. SHANNON, *U. S. National Museum.*

In the course of the study of wardite and the associated phosphates from Utah, the authors secured from the late Colonel Roebling a specimen of the kalkwavellite from Dehrn, described in 1869 by Kosmann and the present paper is the result of a study of this specimen.

The specimen is a brecciated phosphorite and the fragments are coated with a white vitreous crust, averaging about one-half millimeter in thickness, of a finely crystalline mineral; perched on these crusts in the cavities are numerous aggregates of radiating needles, some of them five millimeters long. The specimen is about six centimeters long and nearly half as thick and the crusts and spherulites each make up several per cent of the specimen.

DEHRNITE

The crystalline crusts that coat the fractures of the phosphate rock failed to agree with any known mineral in composition although similar to the meteoritic calcium-sodium phosphate merillite except that the soda is approximately half replaced by water and carbon dioxide. The same mineral was also found in small amounts associated with the wardite of the Utah locality. The name dehrnite is proposed for the mineral from the locality.

This mineral forms grayish or greenish white crusts of fibrous to bladed crystals. The individual crystals were not suitable for goniometric measurement.

Dehrnite has a hardness of about 5 and a specific gravity of 3.04 as determined by floating crystals in a heavy solution. It fuses readily to a white enamel ($F=2$), and on further heating to a white opaque bead. It has a perfect basal cleavage, and a hexagonal outline. It is uniaxial, negative, and $\omega=1.622$, $\epsilon=1.614$.

About half a gram of carefully purified mineral was available for the analysis. This material contained a few per cent of impurities mostly the phosphorite rock. Most of the grains are clear but some

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are much clouded from minute gas cavities. The crusts show a concentric structure with thin layers of a slightly different index of refraction from the average.

The analysis by Shannon and the ratios are given below.

ANALYSIS AND RATIOS OF DEHRNITE

	Per cent	Ratios	
Insol.	0.12		
CaO	50.88	.907	1.00×7
Al ₂ O ₃	tr.		
P ₂ O ₅	37.12	.261	1.01×2
K ₂ O	1.20	.013	} 99×1
Na ₂ O	7.11	.115	
H ₂ O+ 112°	1.52	.093	} 98×1
H ₂ O- 112°	0.16		
CO ₂	1.49	.034	
F, Cl	none		
	99.60		

The phosphate from the Utah locality occurs in minute, zoned, hexagonal prisms or plates in the porous parts of the "wardite" specimens. It is uniaxial negative, and the indices of refraction of the main, central part are: $\omega = 1.640$; $\epsilon = 1.633$; those of the outer zone are: $\omega = 1.600$; $\epsilon = 1.586$.

ANALYSES AND THEORETICAL COMPOSITIONS OF DEHRNITE

	1. Utah	2. Dehrn	3. 7CaO · Na ₂ O · 2P ₂ O ₅ · H ₂ O	4. 7CaO · $\frac{1}{2}$ Na ₂ O · $\frac{1}{2}$ K ₂ O · 2P ₂ O ₅ · H ₂ O	5. 6CaO · Na ₂ O · 2P ₂ O ₅ · H ₂ O	6CaO · $\frac{1}{2}$ Na ₂ O · $\frac{1}{2}$ K ₂ O · 2P ₂ O ₅ · H ₂ O
Insol.		0.12				
Al ₂ O ₃	1.0	tr.				
CaO	47.7	50.88	51.85	50.77	48.01	46.94
MgO	0.8					
Na ₂ O	4.4	7.11	8.20	4.02	8.86	4.33
K ₂ O	5.9	1.20		6.09		6.56
P ₂ O ₅	35.7	37.12	37.57	36.79	40.56	39.66
H ₂ O+	1.9	1.52	2.38	2.33	2.57	2.51
H ₂ O-		0.16				
CO ₂	3.3	1.49				
F, Cl	—	none				
Sum	100.7	99.60	100.0	100.0	100.0	100.0

The analysis of the Utah mineral by Shannon is given in Column 1, that of the mineral from Dehrn in Column 2, the theoretical composition ($7\text{CaO} \cdot \text{Na}_2\text{O} \cdot 2\text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$) in Column 3, and for the mineral with equal molecular proportions of soda and potash in Column 4. In Column 5 is given the theoretical composition for $6\text{CaO} \cdot \text{Na}_2\text{O} \cdot 2\text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$, and in Column 6 that for $6\text{CaO} \cdot \frac{1}{2}\text{Na}_2\text{O} \cdot \frac{1}{2}\text{K}_2\text{O} \cdot 2\text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$.

Both analyses agree closely with the formula $7\text{CaO} \cdot \text{Na}_2\text{O} \cdot 2\text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$ but they are not very different from the simpler formula $6\text{CaO} \cdot (\text{Na}, \text{K})_2\text{O} \cdot 2\text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$. The Dehrn mineral is nearly a pure soda dehrnite while the Utah mineral has nearly as large a molecular proportion of K_2O as of Na_2O .

The formula $6\text{CaO} \cdot \text{Na}_2\text{O} \cdot 2\text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$ is similar to that assigned to merrillite ($6\text{CaO} \cdot 2\text{Na}_2\text{O} \cdot 2\text{P}_2\text{O}_5$) and as the optical properties of this mineral and merrillite are similar, the former seems to be a merrillite in which half the Na_2O is replaced by H_2O .

The optical properties of the hydrous phosphates from the two localities and of merrillite are given below for comparison. All are uniaxial and probably hexagonal.

DEHRNITE				MERRILLITE
Dehrn		Utah		
		Border	Core	meteorite
ω	1.622	1.600	1.640	1.623
ϵ	1.614	1.586	1.633	1.620
Sp. gr.	3.04			3.10

CRANDALLITE

The white fibrous aggregates, later than and attached to the dehrnite crusts are no doubt the mineral analyzed by Kosmann and called kalkwavellite. It seems to be identical with crandallite, described in 1917 by Loughlin and Schaller.² The kalkwavellite name is misleading as the mineral has neither chemical nor optical similarity to wavellite and the authors propose that the name crandallite be retained for the species.

Crandallite occurs in creamy-white rather brittle prismatic fibers that radiate from a center to form rosettes up to 10 millimeters across. It has a perfect cleavage parallel to the length. It

² Loughlin, G. F., and Schaller, W. T. Crandallite, a new Mineral, *Am. J. Sc.*, (4) 43, 69-74, 1917.

is optically positive, has a moderate axial angle, and its indices of refraction are: $\alpha=1.59$, $\gamma=1.60$; X is parallel to the elongation and Z is sensibly perpendicular to the cleavage. The mineral is probably orthorhombic and the elongation may be taken as c and the cleavage as (100). The optical orientation then becomes $X=c$, $Z=a$.

The crandallite needles carry very numerous minute inclusions, many of them with cuneiform shape.

The crandallite is fusible at about 2 to 3 to a white enamel. On further heating the mineral swells away from the matrix and finally fuses to a white bead. It is difficultly soluble in nitric and hydrochloric acids, both before and after ignition.

An analysis of the spherulites that carried an abundant but uncertain quantity of inclusions of unknown character was made by Shannon and is shown in column 1, the ratios in column 2, the analysis by Kosmann in column 3, that of Schaller on the Utah mineral in column 4, and the theoretical composition of $\text{CaO} \cdot 2\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 6\text{H}_2\text{O}$ in column 5.

ANALYSES AND RATIOS OF CRANDALLITE

	Shannon	Mol. ratios of 1		Kosmann ^a	Utah Crandallite	Theoretical
SiO ₂	4.92					
Al ₂ O ₃	37.52	410	104×2	35.65	38.71	40.03
P ₂ O ₅	25.24	198	100×1	28.39	27.09	27.82
CaO	11.04	162	82×1	14.86	7.50	10.98
SrO					2.21	
MgO	0.24				0.94	
H ₂ O	17.90				18.86	21.17
H ₂ O—	1.00	1166	95×6	21.09	1.29	
CO ₂	2.54				3.80	
SO ₃					3.80	
	100.40			99.99	104.20	100.00

^a Deducting 15 per cent of impurities.

The analyses agree rather closely with the formula $\text{CaO} \cdot 2\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 6\text{H}_2\text{O}$. The mineral is too intimately admixed with a considerable amount of impurities to permit an entirely satisfactory interpretation of its composition or accurate determination of any of its properties.

THE MINERALS OF THE PHOSPHATE NODULES FROM NEAR FAIRFIELD, UTAH¹

ESPER S. LARSEN, *Harvard University*,
and

EARL V. SHANNON, *U. S. National Museum*.

INTRODUCTION

In 1894, Mr. F. T. Millis of Lehi, Utah, sent to the United States National Museum a nodule about seven inches across that was made up mostly of a yellow material in which are embedded several small nodules of green variscite. The green variscite and yellow mineral are separated by a narrow layer of a white powdery material. R. I. Packard² made partial analysis of all three of the materials.

Later a considerable number of these nodules were secured by Ward's Natural Science Establishment and Dennison³ analyzed and gave the name of wardite to the light green to bluish green mineral of concretionary habit which he found in many of the nodules.

In the early spring of 1923 the authors undertook to study again these nodules and the present paper is the result. The specimens in the United States National Museum were first studied and later those at Harvard University and a large collection kindly lent us by Ward's Natural Science Establishment. We take this occasion to thank Mr. George L. English and the Ward's Natural Science Establishment for their generosity in placing their whole collection of the nodules at our disposal.

Our study was rather intensive but not exhaustive. Calcite, variscite, and wardite are present in most of the nodules and eight new minerals were segregated, studied optically and physically, and analyzed, and some others were studied optically but were not segregated for analysis. Others are no doubt present and any trained mineralogist aspiring to describe and name a new mineral can probably find one in these nodules by careful search. The original deposit, if it should ever be opened up again, will

¹ Published with the permission of the Director of the U. S. Geological Survey and the Secretary of the Smithsonian Institute.

² Packard, R. I. Variscite from Utah, *Am. J. Sc.*, [III], 47, p. 297, 1894.

³ Dennison, J. M. Wardite, a new basic phosphate of alumina, *Am. J. Sci.*, [IV], 2, p. 154, 1896.

be a most interesting mineral locality and should yield many new species.

In the summer of 1927, Larsen made a short visit to the wardite locality and collected a few poor specimens from the dump. The deposit is located a short distance north of the north fork of the south fork of Clay Canyon, about three-quarters of a mile above the road and clay pit, 2.8 miles from Fairfield South, and $5\frac{1}{2}$ miles west of Fairfield, Utah. It was prospected by a short tunnel and drift. The phosphate nodules occur along thin discontinuous veinlets in gray limestones. One outcrop is 20 feet above the tunnel and a second is said to be covered by the dump. Very little of the phosphates are now exposed.

DESCRIPTION OF THE HAND SPECIMENS

Most of the minerals described in the following paper are new species. A list of the species, their chemical composition, optical and other properties are given in table 12, near the end of this paper.

The nodules are ellipsoidal or discoidal in shape and vary in size from a fraction of an inch to 8 inches. They are imbedded in a matrix of quartz and calcite. The phosphate nodules are sharply separated from the quartz-calcite matrix. Most of the smaller nodules are made up almost entirely of a compact sulphur yellow material with a little coarsely crystalline calcite, and have a central cavity with rough walls. The yellow material is in concentric layers of slightly differing color and density and resembles a metacolloid. It is made up chiefly of pseudowavellite.

Some of the large nodules are very similar but most of them have a number of minerals, arranged more or less in concentric layers or in part lining or filling cavities. The whole mass has the appearance commonly ascribed to a metacolloid, with concentric layering, shrinkage cracks, etc.

Some of the nodules have an outer shell, rarely as much as a millimeter thick which is gray to nearly colorless and vitreous. Veinlets of this material also cut across the yellow. It is an intimate mixture of pseudowavellite and deltaite. Other nodules made up largely of the yellow pseudowavellite have lenses or less regular cavities lined with calcite or with white fibrous or spherulitic crusts. These are dennisonite, lehiite, or an undetermined mineral. In some the original cavity is entirely filled. In a few cavities are perched plumes made up of small white hexagonal



PLATE I. Phosphate nodule in the collections of the National Museum.

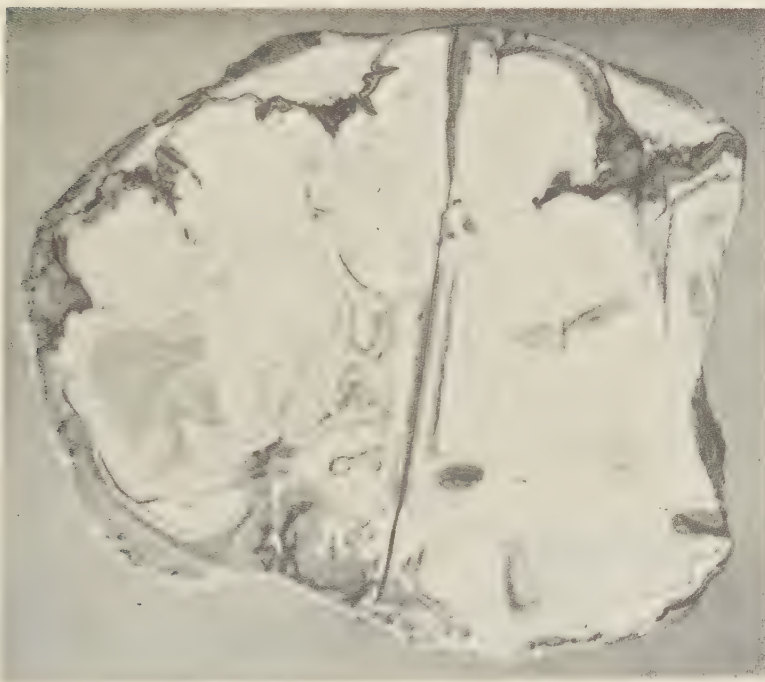


PLATE II. Polished phosphate nodule in the collections of the National Museum.

needles of dehrnite or lewistonite. Some of the yellow nodules have cores of bright green variscite. Rare nodules have a core of variscite, surrounded by a layer a millimeter or so thick, of white, powdery or chalky pseudowavellite (?), outside of which is a layer about a centimeter thick of dense, banded deltaite that looks like chert and has some thin colorless layers. Beyond this and sharply separated from it is an outer crust about a centimeter thick of cream color and made up of oölites a millimeter across in a scant matrix. They are intergrowths of pseudowavellite and deltaite.

Many of the nodules have irregular layers, mostly less than a millimeter across, of clear vitreous light green granular wardite. This is closely associated with vitreous, thinly banded white crusts of millisite resembling banded chalcedony. In places these two crusts were clearly deposited on the yellow pseudowavellite or on the variscite and the millisite was first deposited. This relationship is especially well shown where spherulites of these minerals are attached to the pseudowavellite or penetrate the variscite. The white millisite in all cases forms the center of the spherulites and the pale green wardite forms the outer crust. In a few specimens layers of the two kinds alternate in the spherulites. In a few specimens the light green wardite forms rude crystals, half a millimeter across, in the more porous parts.

In a few of the nodules, crusts, rarely much over a millimeter thick, of a clear, glassy, cleavable mineral (gordonite), separate the variscite from the other minerals. In some specimens this crust completely encrusts the variscite, in others it forms a lens on one side of the variscite. In cavities some good crystals of this cleavable mineral can be found.

In a very few nodules, crusts very much like those described in the preceding paragraph and occupying the same position, are made up of a mineral with a somewhat more platy curved micaceous cleavage (englishite).

METHODS OF STUDY

In the study of minerals that are so finely crystalline, so intimately intergrown, in such small masses, and so similar in their physical, optical, and chemical properties, the petrographic microscope and the immersion method are well-nigh indispensable. Heavy solution separations are necessary and for the micaceous

mineral, tapping on a sheet of paper was the only means found of cleaning it from variscite. The electromagnet was of no use as all of the minerals were found to be nonmagnetic, even to a strong electromagnet. Hand picking was found useful for preliminary separation and for getting rid of the bulk of a colored mineral like variscite. At every step in the process of preparing the samples for analysis the products were checked with the immersion method and the microscope and the next step largely depended on the result of this examination. Patience and no little thought and ingenuity were required even for what seemed to be a simple heavy solution separation, as the results were rarely just what one expected and still more rarely what one wanted. It is usually necessary to pass the sample through several liquids with different gravities.



FIG. 1. Separatory funnel.

Carbon tetrachloride (gravity = 1.60), bromoform ($g. = 2.90$) and methylene iodide ($g. = 3.32$) were used as heavy solutions. They can be mixed to form a solution of any desired gravity.

Most of the samples were small and on account of the inevitable loss of material in removing the last few per cent of impurities most of the samples analyzed contained some impurities. These impurities were determined under the microscope and the proportion estimated by counting the grains. A correction was then made in the analysis.

The separating funnels found most satisfactory have straight, steep sides and an open top as shown in figure 1. The hole in the stopcock should be large enough to allow the coarsest particles used to pass through easily but not so large as to allow the liquid

to flood through too quickly when the stopcock is opened wide. A diameter of about 3 millimeters for the opening is found satisfactory but it can be larger for a large funnel. It is very necessary that the slope of the funnel continue regularly to the opening in the stopcock as a shoulder above the stopcock will prevent some of the settled sand from coming through the stopcock readily. The upper lip of the funnel is ground and a cover of ground glass or a watch glass can be used.

The sample to be separated with heavy solutions is ground only so fine as is necessary to separate the different minerals as a coarse powder can be separated more quickly with a cleaner product than a fine one. Twenty mesh is very readily handled but for most of the minerals of the phosphate nodules finer grinding was required. Anything that will hold on a 200 mesh screen can be readily separated, and even finer material can be used but with much more difficulty. The grinding should be done in stages so as to produce the minimum amount of fines—grind a little, then screen, regrind the part that is still too coarse, and repeat until all passes the screen. Sizing before attempting to separate is helpful if the sample is large but is less necessary if the sample is small. Where material finer than 200 mesh is present the sample may have to settle over night or even longer before the liquid is clear, and the settling complete. Where much fine material is present the powder must be passed through the liquid repeatedly to get a clean product. A centrifuge is necessary for very fine material.

Before attempting a separation the powder is examined under the microscope to determine the minerals present, to see if the grains are made up of one mineral, as far as possible, and to recognize alteration products, gas inclusions, inhomogeneity, etc.

If the specific gravity of the minerals is known, a liquid is chosen that is between the minerals to be separated and preferably near that of the mineral it is desired to get in a pure state, so as to eliminate mixed and doubtful grains. If the specific gravity of the minerals is not known they may be roughly estimated from their mean index of refraction or a liquid can be prepared by immersing small grains of the minerals. Finally, the powder can be put into any liquid and the gravity of the liquid changed by adding a liquid with higher or lower gravity, as desired until a liquid is found that will give a satisfactory separation.

The funnel is about half filled with the liquid, the powder added,

and more liquid to wash down and mix with the powder. It may be stirred with a stirring rod. Any mineral on the sides of the funnel should be washed down. After the minerals have settled, if the light mineral is wanted, and no great economy of material is necessary, the heavy part is allowed to pass through the stopcock on to a coarse filter paper. It is washed with alcohol and the washings saved to recover the heavy solution by washing out the alcohol with water.

The light part is stirred into the solution again and the sides washed down with more liquid. By repeating this several times all of the heavy material is separated out and the light part is filtered from the liquid, washed with alcohol, dried, and examined with the microscope to determine what must be done next. The heavy part is also examined. By using a lighter liquid a cleaner product may be had by sacrificing some of the mineral.

The next step will depend on the results of the first trial. With fine grained, unknown minerals one trial is rarely sufficient and several are usually required.

If it is desired to get a clean product of the heavy part, it is run into a second separatory funnel that is two-thirds full of solution and allowed to settle through this liquid. Three separations are usually sufficient unless the powder is very fine or a large amount is used.

The gravity of any liquid can be changed in the funnel by adding a liquid of different gravity.

It was found impossible to separate the englishite from the variscite with a heavy solution. The micaceous nature of the englishite was therefore taken advantage of and the fine powder, made up of about equal amounts of each mineral, was placed on a sheet of paper or a filing card and by gently shaking and tapping, the rounded grains of variscite rolled off the card while the flakes of englishite remained behind. A piece of soft filter paper or japanese lens paper was found to hold the coarser flakes better than ordinary paper. By repeated cleaning in this way a product with less than 10% of variscite was procured. It was found best to retain only a little of the englishite at each operation, and to recover from the tailings repeatedly. Unless great care is taken much of the sample, and chiefly the platy mineral, will be lost by floating in the air.

In the microscopic study thin sections gave chiefly the relation

of the different minerals and crusts to each other while the immersed powders were found most valuable. In studying the powders all the optical properties of the minerals were determined. Interference figures were necessary with these minerals more than is commonly the case as several of the commonest minerals of the nodules have indices of refraction that are somewhat variable and between 1.59 and 1.64, and the birefringence of most of the minerals is near 0.01. The habit, form, extinction angles, elongation, etc., are variable and only partially characteristic. Until considerable familiarity with all the minerals was had, it was necessary to get all the properties of a mineral before it could be identified with assurance.

In the course of the heavy solution separations many immersions were made—probably over a hundred for some of the separations. This involves less time than might be thought as a powder with only a few minerals, all of whose properties are known, can be examined and rough estimates of the proportions of each of the constituents made in a few minutes.

The specific gravity was determined by floating in heavy solutions or in part by noting the specific gravities of the liquids that just settled and just floated the mineral in the course of the heavy solution separation. Most minerals settle over a moderate range of specific gravities due to included gas pores or other inclusions. The clearest crystals are the heaviest and the specific gravity of the mineral is not far from that of the liquid in which a few of the purest mineral grains just settle.

The study began with a careful examination of the hand specimens in the National Museum collections. Each crust or layer was then studied with the microscope by breaking or scraping with a knife or file enough material for a few immersions. The properties of all the minerals in the powder and their relations to each other were determined, their proportions roughly estimated and the suitability of the material for yielding samples of any of the minerals considered.

The crust or lens that was selected to yield the powder to be analyzed for a particular mineral was then broken out or scraped off with a sharp tool or filed off with a file and the mineral purified as described in the preceding pages. Most of the minerals are too hard to scrape off easily with a knife but a file worked well through it yielded a rather fine powder. Hand picking was resorted

to where necessary and possible and in most cases it was found expedient to remove some of the larger pieces of impurities by hand picking.

METHODS OF ANALYSIS

The samples which were available for analysis were of small size and had, in every case, been prepared at very great cost of time and labor. In few cases was it possible to use portions of more than 100 milligrams of any of the minerals for the analytical procedure. This made it necessary to follow a routine of methods which was simplified as far as possible to avoid the use of excessive quantities of reagents. Certain preliminary conditions proved fortunate. First, the minerals concerned, with few exceptions, were free from volatile substances other than water and contained no oxidizable elements so that a fairly exact estimation of the water content could be secured by weighing the loss on ignition. Further, after ignition, all were completely soluble on digestion in warm 1:1 hydrochloric acid. Qualitative tests showed them to be free from more than a trace of iron.

For the analyses (made by Shannon) the samples were placed in a small platinum crucible, heated for two hours at 110° C. and weighed, then heated slowly to a full red heat. After the second weighing the mineral was dissolved in warm 1:1 hydrochloric acid and the undissolved portion filtered off.

To the chloride solution there next was added a known amount of iron in the form of ferric chloride. This was prepared by dissolving an amount of very pure iron wire, approximately equal to the weight of the sample taken, in a small amount of hydrochloric acid to which a few drops of nitric acid had been added. The solution was then thrice precipitated with ammonia in the presence of an excess of ammonium chloride, the volume of both solutions and reagents being kept small.

From the weight of P_2O_5 , Fe_2O_3 and Al_2O_3 obtained from the weighted and ignited precipitate, the calculated weight of Fe_2O_3 added was deducted, the weight of $P_2O_5 + Al_2O_3$ in the mineral thus being obtained. The precipitate was then carefully mixed with a large excess of sodium carbonate and cautiously brought to full fusion and thoroughly fused over the blast. After cooling this was brought into solution with 1:1 nitric acid and when the solution had become clear, it was heated to boiling and treated

with 60 cc. of ammonium molybdate. The precipitate of ammonium phospho-molybdate was filtered on a small tared gooch crucible. This was dried at 110° C. for one hour and then placed in a small air bath and the temperature held at 450–500° C. for one hour. It was then weighed as $\text{MoO}_3 \cdot 24\text{P}_2\text{O}_5 = 0.03946 \text{ P}_2\text{O}_5$.

In the combined filtrates the lime is precipitated as oxalate and weighed as CaO.

Gonyer's procedure differed from Shannon's in that the P_2O_5 was precipitated with ammonium molybdate immediately after dissolving the sample. The precipitate was then dissolved in ammonium hydroxide and reprecipitated with magnesia mixture. The excess molybdenum was removed from the solution containing the sample and the analysis completed by the usual methods.

When material was available a separate sample was taken for alkalis.

Wardite

Dennison⁴ gave the name of wardite to the light green to bluish green mineral of concretionary habit in the cavities of the nodules from Lewiston, Utah. Wardite has not been accepted as a species but our study shows it to be a definite well-defined mineral and entitled to species rank.

Wardite was found chiefly as pale green granular layers or spherulites but also as nearly colorless thin layers within or on the outside of some of the dirty gray, chalcedonic nodules of millisite and in scattered crystals and thin crusts within the yellow pseudowavellite. It is nearly always distinctly crystalline and granular with individual grains as much as a millimeter across. In a few specimens it forms poorly developed, drusy crystal aggregates in the porous parts but no good crystals were found. Some fairly well formed crystals are embedded in the pseudowavellite and millisite and appear to have an octahedral or similar habit. A few basal sections are eight sided and the mineral is probably tetragonal. It has a perfect basal cleavage.

Wardite has a hardness of 5 and a specific gravity of 2.81. (2.77 Dennison.) It is fusible at 3 with intumescence to a blebby glass. It is difficultly but completely soluble in acid.

It is uniaxial positive and its indices of refraction vary slightly (± 0.005). Those of the analyzed powder are, $\omega = 1.590$, $\epsilon = 1.599$.

⁴ Dennison, J. W. *Loc. cit.*

Some of the green layer was carefully picked out of the specimens and purified with heavy solution. A product weighing two grams was thus obtained for analysis which contained about 8% of millisite.

The analysis by Shannon and the ratios are shown in Table 1, together with the older analyses by Dennison and the theoretical composition.

TABLE 1.
ANALYSIS AND RATIOS OF WARDITE

	1. Analysis Dennison	2. Analysis Shannon	2a. Corrected for Impurities	2b. Ratios	Theoretical $2\text{Na}_2\text{O} \cdot \text{CaO} \cdot$ $6\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot$ $17\frac{1}{2}\text{H}_2\text{O}$
Al_2O_3	38.25*	36.54	36.6	.359 = 60 x 6	36.77
FeO	0.76				
CaO		3.30	3.0	.054 = 54 x 1	3.36
MgO	2.40				
CuO	0.04				
Na_2O	5.98	6.68	7.0	.113 = 60 x 2	7.44
K_2O	0.24	0.73	0.6	.007	
P_2O_5	34.46	34.76	34.9	.245 = 61 x 4	34.08
H_2O	17.87	17.85	17.9	.999 = 58 x 17	18.35
	100.00	99.86	100.0		100.00

* By difference.

The analysis of Shannon corresponds very closely to the formula $2\text{Na}_2\text{O} \cdot \text{CaO} \cdot 6\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot 17\text{H}_2\text{O}$. That of Dennison is very similar but was probably made on a less pure sample.

The Identity of Soumansite with Wardite

In 1910, Lacroix⁵ gave the name of soumansite to a mineral that he found in specimens from Montebbras. Soumansite occurred as tetragonal crystals of pyramidal habit implanted on amblygonite. It has a hardness of $4\frac{1}{2}$ and a specific gravity of 2.87. It is optically positive and in part uniaxial, in part divided into four biaxial segments. A specimen kindly furnished the authors by Professor Lacroix has a small axial angle and fragments tend

⁵ Lacroix, A. *Min. de la France*, 4, 451, 1910.

to be normal to the acute bisectrix, indicating a perfect basal cleavage. $\alpha=1.586$, $\beta=1.586$, $\gamma=1.595$.

A partial analysis by Pisani gave: $P_2O_5=31.5$, Al_2O_3 36.5, and blowpipe tests indicated considerable H_2O , Na_2O , and F.

The chemical composition of soumansite as far as it has been determined, is, therefore, essentially the same as that of wardite and, as the crystal form and the optical properties are almost identical, the two minerals are without doubt identical. As the name wardite has priority, it should be retained for the species.

Pseudowavellite

A mineral that agrees with pseudowavellite, recently described by Laubmann⁶ is one of the chief minerals of most of the nodules examined by us. It constitutes most of the yellow crusts. It is rather dense and is made up of successive concentric layers of somewhat different color and texture. For the most part it shows no distinct crystalline texture megascopically. The microscope shows that it is composed of crusts of subparallel fibers or of matted fibers which are rather coarse in some layers and extremely fine in others. The fibers in the more coarsely crystalline layers tend to grow normal to the walls. The fibers have a negative elongation and the coarsest give a positive uniaxial interference figure. The indices of refraction vary from $\omega=1.59$ to 1.625 probably due to admixtures. The coarsest and best grains have ω near 1.620.

A sample of the yellow crusts made up of very finely fibrous material was cleaned and made as homogeneous as possible by heavy solutions and analyzed. The average indices of refraction of the analyzed material are $\omega=1.618$, $\epsilon=1.623$. It has a specific gravity of 2.92 and a hardness of 5. It fuses at $2\frac{1}{2}$ to a white bead. Nearly two grams of the mineral were separated as usual for analysis and were found to contain about 6 per cent of fibers of dennisonite and to have indices of refraction that vary only 0.01 from the average of the material. The analyses by Shannon and the ratios are shown in table 2 column 1.

A few of the nodules have a thick yellow layer outside of and sharply separated from a layer of gray, chalcedony-like material that is made up mostly of oölites about a millimeter across with some irregular bodies of compact vitreous yellow material. Both

⁶ Laubmann, H. Die Phosphat-Mineralien und Edelerden des Amberg-Auerbacher Erzkörpers, *Geogn. Jahres*, XXXV, 202-3, 1922.

the oölites and the vitreous parts are made up of two minerals intimately intergrown. Similar vitreous material, partly yellow but mostly gray is very common in the nodules and is commonly associated with the yellow fibrous pseudowavellite. In part it forms an outside shell to the nodules and in part is present as veinlike bodies cutting the pseudowavellite. The spherulites are formed of rather coarse fibers radiating from the center in four bundles or sheaves of fibers in the four quadrants. The vitreous crusts and veinlets are granular in texture. Both kinds are made up of two minerals the chief of which is in relatively coarse crystals and the other has a higher index of refraction, and is embedded in the first as fibers, rods, or prisms. The two extinguish together, have the same birefringence, and orientation so that the mixture looks homogeneous between crossed nicols. They are sharply distinct without gradation and stand out prominently when the powder is immersed in a liquid with an index of refraction between that of the two minerals, and the index test made by lowering the condenser or shading one side of the field.

The two minerals are distinct without any gradation and have uniform properties in all the specimens whether in the yellow pisolites, the green pisolites, the yellow or gray massive material, or the gray vitreous borders and veinlets in the yellow, fibrous pseudowavellite. The mineral that forms the greater part of the material and is the host is pseudowavellite. It makes up about three-fourths of most of the mixture. It is in grains up to one-half millimeter across. It has a hardness of about 5 and a specific gravity of 2.88. It fuses at $2\frac{1}{2}$ to a white enamel. It is uniaxial positive and $\omega = 1.622$, $\epsilon = 1.631$. It probably has a perfect basal cleavage. It may belong to the same crystal system as deltaite, which is trigonal. Its properties were very uniform throughout the numerous specimens examined.

Considerable difficulty was experienced in separating the two minerals but after grinding to pass a 200 mesh sieve and repeated separations, and discarding mixed grains, a sample of the pseudowavellite was prepared that weighed 0.5 grams and was estimated to carry only 10 per cent of deltaite. This sample was analyzed by Gonyer. The analysis is shown in column 2, table 2, the analysis corrected for the admixed deltaite and the ratios follow.

The analyses and ratios of the yellow crusts and of material in the oölites separated from deltaite from Lewiston, Utah,

TABLE 2.
ANALYSES AND RATIOS OF PSEUDOWAVEILLITE

	1. Yellow crusts		2. Öölites		3. Auerbach	4. Theoretical $5\text{CaO} \cdot 6\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot 18\text{H}_2\text{O}$
	Anal.	Corrected	Ratios	Anal.	Corrected	Ratios
Al_2O_3	34.15	35.3	.348 = 6 x 58	35.92	36.8	.360 = 7 x 51 or 6 x 60
Fe_2O_3						
Rare earths						
CaO	15.30	13.2	.236 } = 5 x 58	14.74	13.8	.246 } = 5 x 54
MgO	2.06	2.1	.052 }	0.72	0.7	.017 }
Na_2O				0.33	0.3	.005
K_2O				0.13	0.1	.001
P_2O_5	32.23	31.7	.223 = 4 x 56	30.53	30.3	.213 = 4 x 53
H_2O^+	17.50	17.7	.998 = 18 x 55	17.39	18.0	.999 = 18 x 56
H_2O^-						
	101.24	100.0		99.76		101.38
						100.00

are shown in columns 1 and 2 of table 2, the analyses by Kieffer of the Auerbach, Bavaria, mineral in column 3, and the theoretical composition in column 4. The agreement is reasonably close. The Utah mineral has some of the CaO replaced by MgO, while the Auerbach mineral has some of the Al_2O_3 replaced by Fe_2O_3 , and carries some BaO and rare earths. The mineral from Auerbach, according to Laubmann, is in trigonal prisms, is uniaxial positive, has a perfect basal cleavage, indices of refraction between 1.627, and 1.655 and a birefringence of 0.015. It is soluble only in hot concentrated H_2SO_4 . It occurs on wavellite in iron ores. Both the chemical compositions and the optical and other physical properties show the identity of the Utah mineral with the pseudo-wavellite. The formula $5\text{CaO} \cdot 6\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot 18\text{H}_2\text{O}$ seems to fit the analyses.

TABLE 3. ANALYSIS AND RATIOS OF PSEUDOWAVELLITE(?) BY SHANNON

	1 Analysis	2 Corrected for Impurities	Ratios	Theoretical $3\text{CaO} \cdot 6\text{Al}_2\text{O}_3$ $4\text{P}_2\text{O}_5 \cdot 17\text{H}_2\text{O}$
Al_2O_3	36.40	37.5	.367 = 6 x 61	37.00
CaO	11.80	10.4	.185	10.16
Na_2O	1.40	1.4	.023	} = 3 x 71
K_2O	0.54	0.5	.005	
P_2O_5	31.68	32.6	.230 = 4 x 58	34.34
H_2O	18.40	17.6	.978 = 17 x 58	18.50
CO_2				
	100.22	100.0		100.00

The nearly white chalky crusts, less than a millimeter thick, that line cavities mostly next or near the variscite, is made up chiefly of a mineral in minute hexagonal plates, in part very finely crystalline. It is intimately mixed with calcite and variscite, both in minute crystals. It is uniaxial positive with $\omega = 1.619$ and $\epsilon = 1.627$. In the numerous specimens examined the optical properties of the distinctly crystalline part are about the same. Some of the material is indistinctly crystalline to amorphous and has a mean index of refraction as low as 1.59.

A sample weighing 0.2 grams of the best material available was carefully scraped from a specimen and used for the analysis. It

was estimated to have about 3 per cent of calcite as impurities and was uniform in its optical properties. The analysis, as made and as corrected for impurities, is given in table 3, column 1. It agrees fairly well with the theoretical composition given in column 3. The analysis agrees closely with the formula $3\text{CaO} \cdot 6\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot 17\text{H}_2\text{O}$ which is similar to that of wardite with the soda replaced by lime. Crystallographically wardite appears to be tetragonal while this mineral is in hexagonal plates.

Until better evidence is available, it seems best to consider these hexagonal plates a variety of pseudowavellite.

Deltaite, A New Mineral

The mineral intergrown with pseudowavellite in the oölites as described in the section on pseudowavellite has a characteristic Δ form like the Greek letter delta and the name deltaite is proposed for it. It constitutes only about one-fourth of the mixture. The individual crystals are rarely as much as 0.05 millimeters in cross section. The deltaite is partly in fibers but much of it is in rather stout prisms with triangular cross section. Some of these prisms taper at one end and are terminated by well formed, rather steep rhombohedrons at the other. In some grains the cross sections show two triangles of deltaite with the sides parallel but with apices pointed toward each other and nearly touching, giving an hourglass structure. In others four such triangles point toward a center with a thin layer of pseudowavellite between. Deltaite shows a marked tendency to develop crystal boundaries and in nearly every specimen it has the characteristic triangular cross section.

Deltaite has a specific gravity of about 2.95 and a hardness near 5. It is optically positive, and probably uniaxial, $\omega=1.641$, $\epsilon=1.650$.

A sample of the deltaite weighing 0.5 grams, that contained 20 per cent of pseudowavellite was prepared. The analysis made by Gonyer is shown in column 1 table 4 and the corrected analysis and ratios follow.

One of the commonest types of crust about the variscite is a dirty gray, dense, cherty-looking layer which is commonly between the yellow oölitic layer and the variscite. A thin layer of chalky material separates it from the variscite and it commonly carries within it isolated crystals or thin white layers of wardite and

lenses and layers of dennisonite. Some of the crusts are as much as one centimeter across but most are thinner. These gray crusts are made up of matted fibers of a single mineral which appears to be identical with deltaite. This deltaite is tough and has a hardness of 5 and a specific gravity of 2.93. It fused at 2 with intumescence to a white opaque bead. The microscope shows that it is composed of matted fibers with negative elongation. The indices of refraction are: $\alpha=1.630$, $\gamma=1.640$. A sample of this material weighing 2 grams was prepared. It contained no appreciable amount of visible impurities. An analysis of this sample made by Gonyer on 0.500 grams is shown in column 2 table 4.

The chalky layer between the variscite and the gray cherty deltaite appears to be made up of one mineral. It is very finely crystalline to submicroscopic and the larger crystals are uniaxial positive, with $\omega=1.621$, and $\epsilon=1.629$. About 100 milligrams of this material was separated by Larsen and analyzed by F. A. Gonyer. The results are shown in column 3 table 4. Carbon dioxide was present in considerable amount, probably several per cent, but sufficient material was not available for its determination. No calcite could be found in the sample although the mineral is clouded with submicroscopic inclusions, mostly gas pores. The chalky crust has less Al_2O_3 and P_2O_5 and more CaO , MgO , CO_2 and K_2O than the other deltaites. However, it is believed to be deltaite though later work may show it to be different.

The formula of deltaite may be taken as $8 \text{CaO} \cdot 5 \text{Al}_2\text{O}_3 \cdot 4 \text{P}_2\text{O}_5 \cdot 14 \text{H}_2\text{O}$.

Dennisonite, a New Mineral

Many of the specimens especially the parts made up chiefly of the yellow pseudowavellite have scattered thin white crusts, mostly less than 1 mm. across, lining cavities. These crusts have botryoidal to spherulitic surfaces and are made up of rather coarse fibers of a single mineral. The cavities are mostly only a few millimeters long and less than a millimeter in thickness. They are also scattered through the dense gray deltaite. The name dennisonite is proposed for this mineral after J. M. Dennison who first described and analyzed wardite.

Dennisonite is softer than most of the associated minerals and has a hardness of $4\frac{1}{2}$. It has a specific gravity of 2.85.

Dennisonite is in stout fibers that have a negative elongation. Cross sections appear to be hexagonal and to show a perfect basal

TABLE 4.
ANALYSES AND RATIOS OF DELTAITE BY CONYER

	1. Separated from Oolites		2. Gray Cherty Crusts		3. Chalky Layer		4. Theoretical
	Analyses	Corrected for Impurities	Ratios	Analyses	Ratios	Ratios	
Al ₂ O ₃	30.06	28.0	.274 = 5 x 55	29.36	.287 = 5 x 57	.2630 = 4 x 66	28.69
FeO				tr.			
CaO	21.66	24.0	.428	22.95	.409 = 7 x 58	.435	25.22
MgO	0.91	0.9	.022		3.40	.084 = 8 x 67	
Na ₂ O	0.60	0.5	.008		0.33	.005	
K ₂ O	0.15	0.1	.001		1.13	.012	
H ₂ O+	14.23	13.1	.727 = 14 x 52	14.22	.792 = 14 x 57	.793 = 12 x 66	14.15
H ₂ O-				0.04			
CO ₂					some	?	
P ₂ O ₅	32.72	33.4	.235 = 4 x 59	32.84	.231 = 4 x 58	.194 = 3 x 65	31.94
Insol.					27.60		
	100.33			99.41	0.60		

cleavage. The mineral is negative and sensibly uniaxial. The indices of refraction are: $\omega = 1.601$ and $\epsilon = 1.591$.

TABLE 5.
ANALYSIS, RATIOS, AND THEORETICAL COMPOSITION OF DENNISONITE

	Analysis	Corrected for Impurities	Ratios		$6\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot$ $2\text{P}_2\text{O}_5 \cdot 5\text{H}_2\text{O}$
Al_2O_3	12.90	11.82	.116	$= 116 \times 1 \quad 98 \times 1$	12.56
CaO	39.00	40.30	.718	$\left. \begin{array}{l} \\ \end{array} \right\} = 125 \times 6 \quad 106 \times 6$	41.39
MgO	1.41	1.38	.035		
P_2O_5	33.00	33.10	.233	$= 116 \times 2 \quad 98 \times 2$	34.97
H_2O^+	11.10	11.60	.644	$= 129 \times 5 \quad 110 \times 5$	11.08
H_2O^-	0.80				
	98.21				100.00

A sample weighing a little over 0.1 grams was prepared for analysis and was found to contain only a few per cent of the yellow pseudowavellite. The analyses, ratios, and theoretical composition are shown in table 5. Material was not available for a determination of the alkalis or for a check analysis. The analysis agrees rather closely with the formula $6\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{P}_2\text{O}_5 \cdot 5\text{H}_2\text{O}$.

Dehrnite

Small, clear hexagonal crystals present in small amount in cavities in yellow pseudowavellite proved to be dehrnite. Under the microscope these crystals commonly show a core that is sensibly uniaxial and a narrow border that is sharply separated from the core by hexagonal crystal faces and that is divided into six biaxial segments. In all parts the mineral is optically negative. The uniaxial core has $\omega = 1.640$, $\epsilon = 1.633$ and the border, which is clouded with peg-like inclusions and makes up about a third of the crystals, has $\alpha = 1.585$, $\gamma = 1.600$. It has a rather small axial angle. A sketch of the optical orientation is shown in figure 2.

An analysis by Shannon made on about 100 milligrams of these crystals is shown in table 6. The analyzed sample contained very little calcite. It had a specific gravity of 3.09.

Botryoidal crusts of dehrnite about a millimeter thick line cavities and cement fragments of pseudowavellite and deltaite

in a few specimens. These crusts are coarsely crystalline and show slight zoning and a tendency to divide into segments. They have a perfect basal cleavage. The specific gravity is 3.07. They

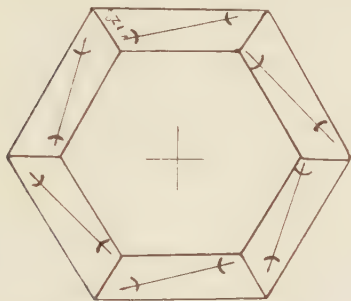


FIG. 2. Optical orientation of dehrnite on the base.

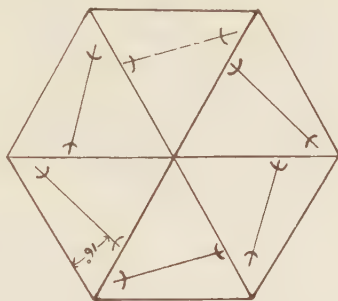


FIG. 3. Optical orientation of lewis-tonite on the base.

are biaxial with a small axial angle and are optically negative. $\alpha=1.610$, $\beta=1.619$, $\gamma=1.620$. An analysis by Gonyer of these crusts is shown in table 6, column 2.

TABLE 6.
ANALYSES OF DEHRNITE

	1. Zoned Crystals	Mol. ratios	2. Crusts	Mol. ratios
Al ₂ O ₃	1.00		0.65	
CaO	47.65	.850	54.86	.978 = 15 x 65
MgO	0.85	.012		
K ₂ O	5.90	.063	0.30	.003
Na ₂ O	4.36	.070	3.70	.060
H ₂ O	1.91	.106	3.02	.168
CO ₂	3.30	.075	1.22	.028
P ₂ O ₅	35.68	.251 = 4 x 63	36.66	.258 = 4 x 64½
	100.65		100.41	
	14CaO · K ₂ O · Na ₂ O · 4P ₂ O ₅ · 2H ₂ O · CO ₂		15CaO · Na ₂ O · 4P ₂ O ₅ · 3H ₂ O	

The formulae derived from the two analyses are given below the analyses. The formula derived from dehrnite from Dehrn is 14CaO · 2Na₂O · 4P₂O₅ · 2H₂O. The three analyses are very close together and the formula for dehrnite may be taken as: 14CaO ·

$2(\text{Na}, \text{K})_2\text{O} \cdot 4\text{P}_2\text{O}_5 \cdot 3(\text{H}_2\text{O}, \text{CO}_2)$, in which some of the alkalis may be replaced by lime. Dehrnite may be a member of the apatite group.

Some of the best colorless needles from another specimen have a clouded core that is sensibly uniaxial, $\omega = 1.623$, $\epsilon = 1.613$, and a clear border that is divided into six segments. On the basal sections each segment gives an extinction at 12° (Z to the trace of the hexagonal face). The axial angle of this outer zone is of moderate size and the mean index of refraction about 1.616. No analysis of this material was made.

Lewistonite, a New Mineral

Some of the hexagonal prisms which are very much like the dehrnite have less alkali and much more water. Chemically they are so different from dehrnite as to give them species rank and the name lewistonite is proposed after Lewiston, Utah.

Lewistonite was found as stout hexagonal prisms associated with the oölites of pseudowavellite and deltaite and as white, powdery crusts lining cavities in pseudowavellite and as amygdules filling the cavities.

The stout crystals associated with the oölites in large part show no central uniaxial core but some of them have a uniaxial core with $\omega = 1.60$. The main outer biaxial zone has an axial angle of about $2V = 42^\circ$. The optical orientation is like that shown in figure 3 and the extinction angle is about 16° . $\alpha = 1.613$, $\beta = 1.623$, $\gamma = 1.624$. The indices vary about ± 0.005 . The specific gravity of these crystals is about 3.06. A sample of little over 100 milligrams of these crystals, made up very largely of the biaxial type, was prepared for analysis. It contained about 7 per cent of pseudowavellite and 3 per cent of deltaite as impurities. The analysis by Shannon is shown in column 1, table 7.

One amygdule weighing 200 milligrams was nearly pure lewistonite. It is made up of stout fibers with negative elongation. It appears to be uniaxial and optically negative. $\omega = 1.621$, $\epsilon = 1.611$. It has a hardness of about 4 and a specific gravity of 3.08. An analysis of this material by Gonyer is shown in column 2, table 7.

Lewistonite appears to have a perfect basal and probably also a perfect prismatic cleavage. It has a hardness of 5 and a specific gravity of about 3.06. It has a formula near $15\text{CaO} \cdot (\text{K}, \text{Na})_2\text{O} \cdot 4\text{P}_2\text{O}_5 \cdot 8\text{H}_2\text{O}$.

TABLE 7.
ANALYSES AND RATIOS OF LEWISTONITE

	1. Hexagonal Prisms			2. Amygdale		3.
	Analysis	Corrected for impurities	Ratios	Analysis	Ratios	
SiO ₂	1.12					15CaO · Na ₂ O · 4P ₂ O ₆ · 8H ₂ O
Insol.	0.60					
Al ₂ O ₃	3.67	0.8	.008	2.53	.025	
CaO	41.41	44.6	.742 = 13 x 57	46.78	.834 = 7 x 119	52.06
MgO	7.10	8.1	.200 = 4 x 50			
K ₂ O	3.71	4.6	.049	1.36	.014	
Na ₂ O	0.47	0.6	.008	4.34	.070	3.85
H ₂ O	8.60	8.2	.456 = 8 x 57	7.69	.427 = 4 x 107	8.92
P ₂ O ₅	32.31	33.1	.233 = 4 x 57	37.92	.257 = 2 x 128	35.17
	98.99			100.62		

Calculated formula 13CaO · 4MgO · K₂O · 4P₂O₆ · 8H₂O
14CaO · 2Na₂O · 4P₂O₆ · 8H₂O

Englishite, a New Mineral

Layers of a clear, glassy, cleavable mineral that resembles crusts of gordonite, and that occupy about the same position in the nodule as gordonite, were found on microscopic examination to be a different species and one that differed from any known mineral. The name englishite is proposed for this mineral after Mr. George L. English.

Englishite is found in layers up to a millimeter thick that lie next to or very near the variscite. It is white to colorless and has a very prominent cleavage. It differs from gordonite in the hand specimen chiefly in that it is more platy and its cleavage surfaces are broad and curved. It has a hardness of about 3 and a specific gravity of about 2.65.

TABLE 8.
ANALYSIS AND RATIOS OF ENGLISHITE

	Analysis	Corrected for Impurities	Ratios	Theoretical $4\text{CaO} \cdot \text{K}_2\text{O} \cdot 4\text{Al}_2\text{O}_3 \cdot$ $4\text{P}_2\text{O}_5 \cdot 14\text{H}_2\text{O} \cdot$
Insol.	1.10			
Al_2O_3	25.21	24.7	.242 = 2 x 121	26.41
CaO	12.80	14.1	.251 = 2 x 126	14.50
MgO	tr.			
Na_2O	1.56	1.6	.026	6.08
K_2O	4.84	5.4	.057	
H_2O^+	16.80	16.5	.916 = 7 x 131	16.29
H_2O^-	none			
P_2O_5	37.89	37.8	.266 = 2 x 133	36.73
	100.20			

It has a highly perfect cleavage and characteristic optical properties. The acute bisectrix is normal to the cleavage. The axial angle is small and the optical character is negative. The birefringence is very faint and the powdered mineral can easily be mistaken for an isotropic mineral. Its indices of refraction vary ± 0.005 ; the average values are: $\alpha = 1.570$, $\gamma = 1.572$. If the cleavage be taken as (001) the orientation is $X = c$. The mineral is probably orthorhombic.

About 180 milligrams of this mineral were prepared for the analysis and the analyzed powder contained about 91% englishite,

2% wardite, and 7% variscite. The analyses by Shannon, the ratios and theoretical composition are shown in table 8. The formula derived from the analysis is $4\text{CaO} \cdot \text{K}_2\text{O} \cdot 4\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot 14\text{H}_2\text{O}$.

Millisite, a new Mineral

Many of the phosphate nodules have layers or irregular crusts of a nearly white, banded material that looks like chalcedony, mostly associated with and interlayered with the green wardite. Many of the spherulites have a white central part of fibers of this mineral and an outer layer of green, granular wardite.

This white fibrous mineral proved to have a composition related to that of wardite but to be biaxial negative. The name millisite is proposed for the species after F. T. Millis who sent the original specimens to the U. S. National Museum.

Millisite has a hardness of $5\frac{1}{2}$ and a specific gravity of 2.83. It fuses at $3\frac{1}{2}$ with slight intumescence to a blebby glass.

The crusts of millisite are made up of successive layers of minute, matted fibers with a mean index of refraction varying from about 1.595 to 1.605. The fibers have negative elongation and are optically negative. The matted fibers appear to be uniaxial but coarser crystals prove to be biaxial with a moderate axial angle. For the analyzed powder the average value for the indices were α about 1.584, β = 1.598, γ = 1.602.

About 0.8 grams of the mineral was prepared for the analyses by hand picking and cleaning with heavy solutions. The sample contained about 5 per cent of wardite and 1 per cent of dennisonite. Two analyses of this material were made and are shown in table 9, together with the composition corrected for impurities, the ratios, and the theoretical composition for $2\text{CaO} \cdot \text{Na}_2\text{O} \cdot 6\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot 17\text{H}_2\text{O}$.

The agreement of the analysis with the theoretical composition is very close and the composition of millisite appears to be near that of wardite with half of the alkalis replaced by lime.

Lehiite, a new Mineral

Crusts that resemble those of millisite but lack the banding and have higher indices of refraction were found in only a few specimens.

A sample selected for analysis had a crust of this mineral up to 3 millimeters thick that is dense white, and without banding. It

TABLE 9.
ANALYSES, RATIOS, AND THEORETICAL COMPOSITION OF MILLISITE, BY SHANNON

	Analyses		Average	Corrected for Impurities	Ratios	$2\text{CaO} \cdot \text{Na}_2\text{O} \cdot$ $6\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot$ $17\text{H}_2\text{O}$
Al_2O_3	36.33	35.73	36.03	36.3	$.356 = 60 \times 6$ $.131 = 63 \times 2$ $.045 \left. \vphantom{\begin{matrix} .045 \\ .018 \end{matrix}} \right\} = 63 \times 1$ $.018 \left. \vphantom{\begin{matrix} .045 \\ .018 \end{matrix}} \right\} = 63 \times 1$ $.238 = 60 \times 4$ $1.000 = 59 \times 17$	36.87
CaO	7.00	6.60	6.80	7.1		6.75
MgO	0.33	0.10	0.22	0.2		
Na_2O		3.00	3.00	2.8		3.73
K_2O		1.64	1.64	1.7		
P_2O_5	33.17	34.04	33.60	33.8		34.22
H_2O	17.60	18.15	17.88	18.0		18.42
		99.26	99.17	100.0		100.00

has a hardness of $5\frac{1}{2}$ and a specific gravity of 2.89. It is in rather coarse fibers, has a very large axial angle and is optically, negative, $\alpha=1.600$, $\beta=1.615$, $\gamma=1.629$. The fibers show a large extinction angle. An analysis by Gonyer of a sample of this material weighing 0.2 grams is shown in table 10.

The formula derived is $5\text{CaO} \cdot (\text{Na}, \text{K})_2\text{O} \cdot 4\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot 12\text{H}_2\text{O}$. This is similar to the formula for deltaite although it is lower in lime and higher in alkalis.

TABLE 10.
ANALYSIS AND RATIOS OF LEHIITE

	Analysis	Ratios	$5\text{CaO} \cdot \text{Na}_2\text{O} \cdot 4\text{Al}_2\text{O}_3 \cdot 4\text{P}_2\text{O}_5 \cdot 12\text{H}_2\text{O}$
Al_2O_3	27.79	.2729 = 4 x 68	26.62
CaO	18.10	.3227 = 5 x 65	18.26
MgO	none		
Na_2O	3.08	.497	4.04
K_2O	2.25	.239	
H_2O	14.19	.7876 = 12 x 66	14.07
P_2O_5	34.64	.2438 = 4 x 61	37.01
Insol.	0.58		
	100.63		

Gordonite, a new Mineral

Layers of clear, glassy, cleavable crystals, mostly less than a millimeter thick, are present encrusting, or very near, the variscite in a number of the nodules. It is one of the rarer but best crystallized of the minerals in the specimens. A study of this material showed it to be related to paravauxite with the iron replaced by magnesia and the name gordonite is proposed for the mineral after Mr. S. L. Gordon who first described paravauxite.

Good crystals of this material were not available. However, a careful search may be rewarded by better crystals than those found. The largest and most characteristic terminal face on gordonite corresponds rather well with the base of paravauxite, if the crystals are set up in the position of the latter, and are considered triclinic, as is paravauxite. The most prominent faces in the prism zone then correspond to the prominent forms of paravauxite.

Thus good signals are reflected from (010), and ($1\bar{1}0$). The front pinacoid (100) is a narrow line face. The form ($4\bar{9}0$) is not well developed. The data at present available are not sufficient for establishing an axial ratio, and not of first quality, therefore, only a comparison with paravauxite is here given. It is hoped that a careful search will yield better crystallographic material for a further study.

Forms	Symbols	Paravauxite		Gordonite	
		ϕ	ρ	ϕ	ρ
<i>c</i>	(001)	57° 20'	23° 49'	54° 20'	25° 1'
<i>b</i>	(010)	0°	90° 00'	0°	90° 00'
<i>a</i>	(100)	75° 15'	90° 00'	75° 24'	90° 00'
<i>M</i>	(110)	103° 2'	90° 00'	101° 51'	90° 00'
<i>O</i>	($4\bar{9}0$)	130° 22'	90° 00'	130° 34'	90° 00'
<i>S</i>	($2\bar{1}1$)	-85° 46'	68° 03'	-87° 16'	68° 47'

Gordonite has a hardness of $3\frac{1}{2}$, a specific gravity of 2.28 and a fusibility of 3. It is soluble in acids.

It is biaxial positive, $2V$ is about 73° , and $\rho < v$ is easily perceptible. $\alpha = 1.534$, $\beta = 1.543$, $\gamma = 1.558$. The best crystals are lath shaped and have a very perfect cleavage parallel to the length of the laths and about normal to the flat face. Crystals lying on the flat face and cleavage fragments turned on edge give an extinction angle (Z to trace of cleavage) of 23° in the acute angle β . X is about normal to the flat face. The optical symmetry might be mistaken for monoclinic but crystal measurements make the mineral triclinic. The cleavage would be (100).

By careful hand picking and later cleaning with heavy solution about 0.2 gram of material was secured for analysis. The analysis was made by Shannon on 0.1 gram of material and the check analysis was lost. No CO_2 , SO_3 , or NH_3 were found. The water in the closed tube was neutral.

The analyses, ratios and theoretical composition are shown in table 11.

The analysis agrees closely with the formula $\text{MgO} \cdot \text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_6 \cdot 9\text{H}_2\text{O}$.

TABLE 11.

ANALYSIS, RATIOS, AND THEORETICAL COMPOSITION OF GORDONITE

	Analysis	Ratios		MgO · Al ₂ O ₃ . P ₂ O ₅ · 9H ₂ O
Al O ₃	20.68	.203 = 203 x 1	.92 x 1	22.87
MgO	10.01	.225 = 225 x 1	102 x 1	8.97
P ₂ O ₅	32.80	.231 = 231 x 1	105 x 1	31.84
H ₂ O+	16.80	.1944 = 216 x 9	98 x 9	36.32
H ₂ O-	18.20			
	98.49			100.00

Variscite

Variscite is found chiefly in the grass-green knots within the nodules and it was clearly the original mineral of the nodules from which the other minerals were derived. This green variscite is very finely crystalline.

The white, powdery layer that surrounds the green variscite in most of the nodules is made up chiefly of deltaite but it contains more or less variscite in considerably coarser crystals than in the green mass. Some of the white, powdery layers next the green variscite are made up almost entirely of white variscite in relatively coarse crystals.

All of the variscite is in minute tablets with rhombic outline and in some with a short pyramidal face as well. They are biaxial negative, $2V$ is rather large, Y is normal to the plates and Z bisects the acute angle of the rhombs. The indices of refraction for the green part measured $\alpha=1.569$, $\beta=1.586$, $\gamma=1.594$. For the white crystals $\alpha=1.572$, $\beta=1.592$, $\gamma=1.597$.

Unnamed Minerals or Varieties

A considerable number of minerals that could not be identified by their optical properties were found. Only a few of the more conspicuous or common of these will be described; for none of them was material suitable for chemical analysis found.

1. In a few places a uniaxial negative mineral was found with indices of refraction about midway between those of dennisonite and dehrnitë. It was found in the cavities as were dehrnite and dennisonite. It may be a variety of dehrnite which shows considerable variation in its indices of refraction.

2. Other crystals in the cavities resemble dehrnite but have an index of refraction $\omega = 1.650$.

3. Another mineral that was found in small amount in a number of specimens and that appears to replace lewistonite occurs in fibers with negative elongation, weak birefringence and an index of refraction of about 1.62.

4. Somewhat similar appearing fibers with weak birefringence, and partly negative, partly positive elongation, have an index of refraction of about 1.590.

5. Some minute spherulites in cavities have positive elongation and $\alpha = 1.630$, $\gamma = 1.640$.

6. A biaxial form that has no similarity to any of the other forms was found in small amounts as a thin bluish white crust in one of the specimens in the Harvard collection. The crystals are biaxial positive, have a large axial angle and the indices of refraction, $\alpha = 1.607$, $\beta = 1.615$, $\gamma = 1.623$. The mineral is monoclinic and is twinned with (100) as the composition plane. $X = b$, $Y \wedge c = 8\frac{1}{2}^\circ$.

7. A white, porcelain-like crust between variscite and a thick crust of dehrnite proved to be isotropic with $n = 1.575$. Some incipient spherulites are included in the isotropic mass.

8. On one specimen, made up chiefly of yellow pseudowavellite but with some nodules of variscite, a coating of clear glassy prismatic crystals was found surrounding the variscite, much as the gordonite and the lewistonite surround the variscite. These crystals have a hardness of about $3\frac{1}{2}$. They have a very large axial angle, and are optically negative. The indices of refraction are: $\alpha = 1.567$, $\beta = 1.574$, $\gamma = 1.580$. The crystals appear to have two perfect cleavages parallel to the length and give parallel extinction. Z is normal to the best cleavage and X is parallel to the elongation. This is different from any of the other minerals.

PARAGENESIS

The order of deposition of the minerals can be determined in considerable part. The variscite was the first mineral to form. The pseudowavellite and deltaite were derived in part and probably entirely from the variscite. The deltaite is in part later than the pseudowavellite as it occurs chiefly as border zones and veinlets cutting it. It is partly contemporaneous and intergrown with the pseudowavellite. The millisite and wardite are later than the

TABLE 12.
THE COMPOSITIONS AND PROPERTIES OF THE MINERALS OF THE NODULES FROM NEAR FAIRFIELD, UTAH

Mineral	Crys. Sys.	CaO	(Na, K) ₂ O	Al ₂ O ₃	P ₂ O ₅	H ₂ O	Opt. Char.	α	β	γ	2v	Sp. Gr.	H.	Cleav.
Wardite	Tet.	1	2	6	4	17	Un. +	1.590		1.599		2.81	5	(001)
Pseudowavellite	Trig.	5		6	4	18	Un. +	1.622		1.631		2.92	5	
Pseudowavellite	Hex.?	3		6	4	17	Un. +	1.619		1.627		2.92	5	
Deltaite	Trig.	8		5	4	14	Un. +	1.630		1.640		2.95	5	
Dennisonite	Hex.?	12		2	4	10	Un. -	1.591	1.601			2.85	4½	(0001)
Dehrnite	{Ps. hex.	14	2		4	3	{Un. -	1.633	1.640		0°	3.09		(0001)
	{Hex.						{Bi. -	1.581	1.600		med.			
							Bi. -	1.610	1.619	1.620	sm.	3.07		
Lewistonite	{Ps. hex.	15	1		4	8	{Un. or	1.613	1.624	1.624	42° ±	3.06	5	(0001)
	{Hex.						{Bi. -							
Millisite	Mon.?						Bi. -					2.83		
Lehiite	Mon.?			6	4	17	Bi. -	1.584	1.598	1.602	med.	2.89	5½	
Englshite	Mon.?			4	4	12	Bi. -	1.602	1.616	1.629	large	2.65	3	(001)
	Orth.			4	4	14	Bi. -	1.570	1.572	1.572	sm.			mic.
Variscite	Orth.			4	4	16	Bi. -	1.569	1.586	1.594	rather large	2.52	5	
?	Orth.						Bi. -	1.567	1.574	1.580	very large		3½	
Gordonite	Mon.	MgO 1		1	1	9	Bi. +	1.534	1.543	1.558	73°	2.28	3½	(100)
?	Mon.?						Bi. +	1.607	1.615	1.623	large			

deltaite as they are found as crusts and spherulites in cavities and attached to it. The millisite in large part preceded the wardite but there was some alternation. This is especially well shown by the spherulites which have a central part of millisite and outer layers of wardite. The dehrnite, lewistonite, and dennisonite are later than the deltaite and probably later than the wardite. They occur as crystals or crusts lining cavities in the deltaite and pseudowavellite. The age of the gordonite and englishite are uncertain.

All of the minerals are high in phosphoric acid and water. The first minerals to form were high in alumina. Later minerals contained high lime as well as alumina. Still later alkalies took the place of some of the lime and the last minerals were low in alumina, very high in lime and moderate in alkalies. They were also lower in water than the other minerals.

CONCLUSION

The chemical compositions and properties of the minerals of the nodules are shown in table 12.

Wardite is a rather abundant mineral and it occurs as pale greenish or bluish green vitreous crystals and grains in layers associated with the white banded chalcedonic-looking millisite. It is found also in nearly colorless grains associated with deltaite.

Pseudowavellite is the most abundant mineral of the nodules and makes up most of the yellow, matted fibers and over half of the oölites.

Deltaite is next in abundance after pseudowavellite and is present in nearly every specimen. It is intimately associated with the pseudowavellite. It is present in the oölites and makes up most of the gray looking layers and veinlike streaks that cut the pseudowavellite. It also constitutes the white powdery crusts next to the pseudowavellite and dense deltaite and much of the rough yellow linings of the cavities in pseudowavellite.

Dennisonite occurs as white, botryoidal crusts made up of fibers that line cavities in the pseudowavellite.

Dehrnite was found only in very small amount as small hexagonal crystals in cavities in pseudowavellite. Some white botryoidal crusts that cement fragments of some of the nodules are dehrnite.

Lewistonite is also in very small amount. It was found in stout hexagonal prisms in cavities in the oölites and as a white amygdaloidal filling in pseudowavellite.

Millisite is a fairly abundant and rather conspicuous constituent in many of the nodules. It forms white banded chalcedonic-looking layers that are comonly associated with wardite.

Lehiite was found as a white lens or band that resembled millisite but lacked the banding.

Eng'lishite is in very small amount but it is easily recognized where present. It was found only as thin layers next to variscite. Its very perfect, pearly, curved cleavage surfaces serve to identify it.

Gordonite is also in very small amount and it also was found in thin layers next to variscite. It is in glassy, tabular crystals, often in sub-parallel or radiating groups. Its optical properties complete its identification.

LAZULITE FROM CHITTENDEN, VERMONT

CHARLES PALACHE AND F. A. GONYER.

In the Mineralogical Lexicon¹ of Massachusetts published in 1895, Professor Emerson recorded the finding of a waterworn, glaciated pebble containing lazulite in the bed of Hinsdale Brook in the Berkshire Hills. He was not able to locate the source of this pebble and up to this time this is the only recorded occurrence of lazulite in New England.

In 1894, Mr. C. L. Whittle, then of the U. S. Geological Survey and working in Vermont, found near Chittenden, Vermont, ten miles north of Rutland a small vein of lazulite in an Algonkian quartzite. He presented a specimen to the Harvard Mineralogical collection and this has now been analyzed. The material is sufficiently like the description of Emerson's pebble to make it extremely probable that the Chittenden occurrence was the source of the glacial drift boulder. It is here placed on record to establish the presence of lazulite in the New England rocks.

The specimen in hand, no details concerning which were recorded, is a thin hand specimen, about two by three inches, one side covered with deep blue lazulite, the other a coarsely crystalline quartzite with sericite scales and a few rutile needles and hematite grains. The lazulite shows no developed crystals but is in half-inch grains showing good cleavage. The specific gravity, determined by floating in heavy solution is 3.08.

Concerning the analysis Mr. Gonyer makes the following statement: the mineral is soluble after heating; it was therefore heated and after solution a residue of 1.49 per cent. of the original sample remained. This contained 0.33 per cent. of silica and 1.16 per. cent of undetermined nature, probably largely titanium oxide. The soluble material gave the figures of the table.

	PER CENT	MOL. RATIOS	CALCULATED PER CENT
Al ₂ O ₃	33.11	.3238	33.39
FeO	2.59	.0360	} .3430
MgO	12.38	.3070	
H ₂ O+	6.24	.3464	5.88
P ₂ O ₅	46.17	.3250	46.42
	100.49		100.00

¹ Emerson, B. K. *U. S. G. S. Bull.*, 126.

These figures lead to the formula $(\text{Mg, Fe}) \text{O} \cdot \text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$ with

$$\text{Mg}:\text{Fe}=8:1$$

The last column shows the calculated composition for this formula and the correspondence is good. This is then a normal lazulite rather low in iron.

The optical properties, determined by H. Berman are:

$$\begin{array}{ll} \text{Biaxial } (-), 2V=70^\circ \pm & \text{Dispersion perceptible, } \rho < \nu \\ \alpha = \text{colorless} = 1.612 & \left. \begin{array}{l} \beta = \text{light blue} = 1.634 \\ \gamma = \text{blue} = 1.643 \end{array} \right\} \text{all } \pm .002 \end{array}$$

NOTES ON SOME FRANKLIN MINERALS

L. H. BAUER, *New Jersey Zinc Company, and*
HARRY BERMAN, *Harvard University.*

In the course of a year many interesting new facts come to light about the minerals of this famous locality. This paper is a record of some of the more interesting data collected by the authors during the past year.

I. ZINC-BEARING AMPHIBOLE

A recent analysis, by Bauer, of an amphibole occurring at Franklin, long called actinolite because of its external resemblance to that member of the group, has shown that it is really a zinc-manganese-cummingtonite having the general formula, $H_2(Mg, Fe, Zn, Mn)_7(SiO_3)_8$. The zinc has replaced about 15 per cent molecularly of the iron and magnesium. The ratio is Mg:Fe:Mn:Zn=20:18:19:13.

	PER CENT	MOL. RATIOS
SiO ₂	49.74	.828
Al ₂ O ₃	1.72	.017
FeO	12.80	.178
MgO	8.31	.206
ZnO	10.46	.128
MnO	13.79	.194
CaO	0.49	.009
Na ₂ O	0.22	.004
H ₂ O+	2.16	.120
	<hr style="width: 10%; margin: 5px auto;"/> 99.69	

Specific Gravity = 3.44 for the heaviest pieces.

The amphibole occurs as large green prismatic crystals with cleavage angle $m \wedge m' = 54^\circ 28'$. It is imbedded in rhodonite or garnet, in one case in feldspar, and with it occurs ferroschallerite also described in this paper.

The optical properties are as follows:

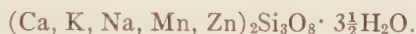
$$\begin{array}{ll} \text{Bx}(-). & 2V = 75^\circ \pm 2^\circ \\ Z \wedge c = 15^\circ. & Y = b. \\ \alpha = 1.657, & \beta = 1.674, \quad \gamma = 1.685. \end{array}$$

II. APOPHYLLITE

Groups of pale pink radiating crystals of apophyllite in crumbly limestone were found in the mine a number of years ago. An analysis, by L. H. Bauer, is as follows:

	PER CENT.	MOLECULAR RATIOS		
SiO ₂	50.90	.844	.844	= 3 × 281
CaO	24.74	.442	.442	
K ₂ O	3.70	.039	.078	.562 = 2 × 281
Na ₂ O	0.42	.007	.014	
MnO	0.47	.006	.006	
ZnO	1.79	.022	.022	
H ₂ O	17.71	.983	.983	= 3½ × 281

The formula derived from this analysis is:



As seen from the analysis this formula agrees well with the determined values. It is of less complexity than any formula heretofore given for this species.

The crystals, not very good for crystallographic measurement, have the forms (001), (111), (110), with the pyramid dominant.

III. BARYSILITE

The original barysilite from Franklin¹ was so scarce that difficulty was encountered in obtaining enough for analysis. An adequate sample recently acquired had prompted a new analysis by Mr. Bauer which is shown below.

	PER CENT	MOLECULAR RATIOS	
SiO ₂	16.84	.280	= 2 × .140
PbO	77.35	.347	
MnO	3.33	.047	.424 = 3 × .141
FeO	0.23	.003	
Al ₂ O ₃	0.59	.006	
CaO	0.21	.004	
MgO	0.78	.019	
ZnO	0.30	.004	
H ₂ O	0.07	.004	
	99.70		

This yields the formula, 3PbO · 2SiO₂.

Barysilite occurs as thin films or narrow veinlets in the ore, associated with garnet, axinite and hardystonite.

The following optical properties were determined by the dispersion method.

Uniaxial (—), $\omega = 2.033 \pm .004$, $\epsilon = 2.015 \pm .004$, for sodium light.

Figure 1 is a dispersion curve for barysilite. The method used in obtaining the values given above and the other values on the curve, may be briefly mentioned since it is useful in obtaining fairly accurate values for material from which prisms cannot be cut and

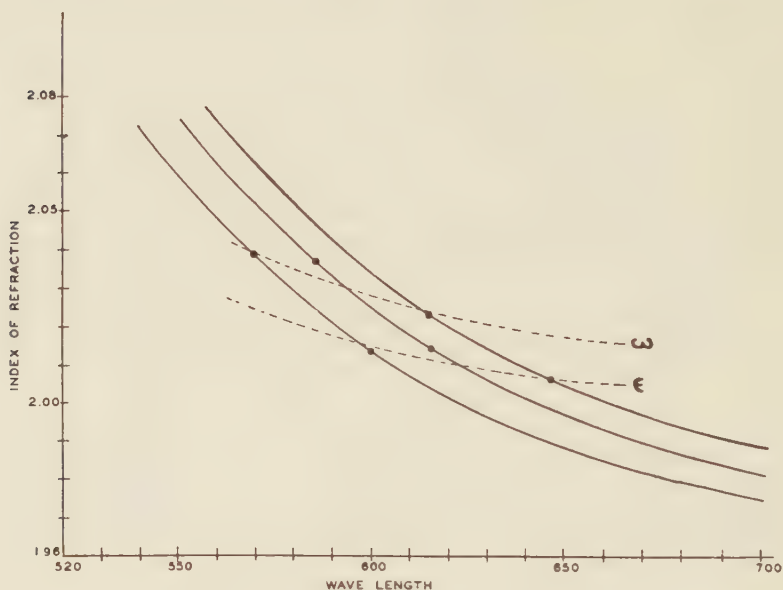


FIG. 1. Index of Refraction of Barysilite.
Solid lines=dispersion curve for melts.
Dotted lines=dispersion curve for barysilite.

immersions in high refractive index melts must be used. The following sketch, illustrates the method.



The melt in which the mineral is to be imbedded is placed in two positions (1 and 2) on the object glass (3) as shown in the sketch. In the first position a prism of small angle is made by the use of a cover glass raised from the object glass on one side. In the second position the mineral is immersed in the same melt in the ordinary manner. The cover glass is then heated so that the melts in the two positions receive identical heat treatment. The prism is then

used to establish the dispersion curve for the melt and the immersion is used to match the mineral and the melt for a particular wave length of light. In this way, by using several melts the dispersion curve for the minerals may be obtained (Fig. 1.). This method is not rapid but it gives fairly accurate results when other methods are not applicable. The principle advantage of the method lies in its freedom from error due to variation in the heat treatment of powders under the usual method.

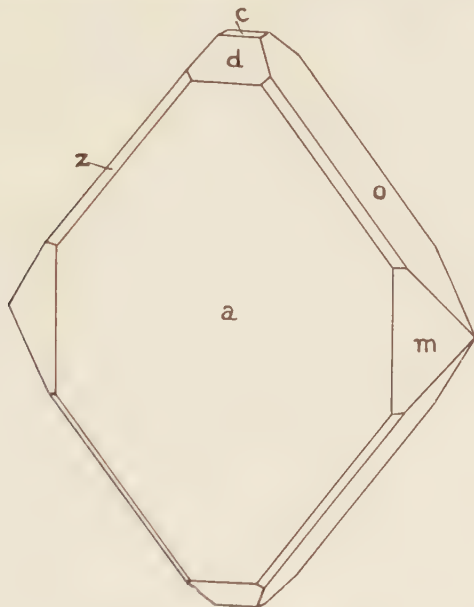


FIG. 2. Celestite, Franklin, N. J.

IV. CELESTITE

This mineral, although known at Franklin, has not been heretofore reported from Sterling Hill. It occurs in a cavity in franklinite ore as good crystals tabular parallel to $a(100)$, Fig. 2. A partial analysis and optical examination indicate that the crystals are pure in composition.

V. CORRECTION

"CLINOZOISITE" FROM FRANKLIN IS CHLOROPHOENICITE

A number of years ago a mineral was found at Franklin which seemed to possess a crystallographic and optical relation to the

minerals of the epidote group. This material was recently described in this journal as clinozoisite,² without an analysis, due to the scarcity of material. Subsequent examination of the material has shown conclusively that it is chlorophoenicite in a somewhat different association, and in slightly better crystals than any found heretofor. The approximate agreement of interfacial angles of epidote and chlorophoenicite by bringing into coincidence the (100) form of the latter with the (001) of epidote, and the generally poor quality of the crystals combined to bring about the misinterpretation. The optical orientation of the two minerals is also quite similar. The following table gives the relations of the angles and optical properties of the erroneously described clinozoisite, and chlorophoenicite.

"CLINOZOISITE"	CHLOROPHOENICITE
$(001) \wedge (\bar{1}01) = 63^{\circ}43'$	$(100) \wedge (106) = 66^{\circ}34'$
$(\bar{1}01) \wedge (\bar{1}11) = 55^{\circ}26'$	$(106) \wedge (146) = 54^{\circ}35'$
$\alpha = 1.684$	$\alpha = 1.682$
$\beta = 1.691$	$\beta = 1.690$
$\gamma = 1.698$	$\gamma = 1.697$
Optical orientation $Y=b$	$Y=b$

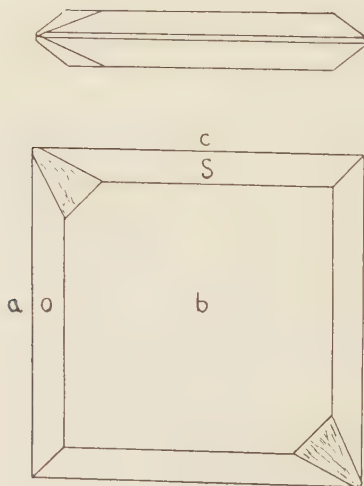


FIG. 3. Datolite, Franklin, N. J. Projection on the side pinacoid (010).

VI. DATOLITE

An interesting new habit of datolite was recently found at Franklin. The crystals are tabular parallel to $b(010)$ with equal development of the forms $o(120)$ and $s(021)$ which have an approximately equal inclination to b . Thus a pseudotetragonal symmetry is developed as shown in Figure 3. The forms present are $c(001)$, $a(100)$, $b(010)$, $s(021)$, $o(120)$ and a vicinal face in the position of a steep positive pyramid.

The determination of the crystals as datolite was confirmed by optical means and a partial analysis.

VII. FERROSCHALLERITE

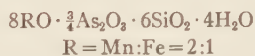
A number of years ago schallerite was described from Franklin.³ The composition is essentially an arseno-silicate of manganese. Recently a variety of this mineral was found at the same mine (1597 pillar, 50 feet south of Trotter Shaft), in which the manganese has been partly replaced by iron, so that this new variety may well be called ferroschallerite. It is interesting to note this replacement relation between the iron and manganese in schallerite because essentially the same relation exists between friedelite and pyrosomalite, two other members of the same group.

An analysis on the ferroschallerite by L. H. Bauer follows:

ANALYSIS OF FERROSCHALLERITE

	PER CENT	MOLECULAR RATIOS	
SiO ₂	31.12	.518	= 6 × .086
MnO	29.22	.422	} .708 = 8 × .089
FeO	17.12	.238	
MgO	0.12	.003	
ZnO	3.63	.045	
As ₂ O ₃	12.46	.063	= $\frac{3}{4}$ × .084
H ₂ O	6.42	.356	= 4 × .089
	100.09		Sp. Gr. = 3.44

This yields the formula:



VIII. MANGANBRUCITE

A single specimen of manganbrucite has been found as a narrow veinlet cutting the franklinite-willemitite ore. The crystals are acic-

ular parallel to the *c*-axis. The individuals are closely compacted to form sub-parallel aggregates with a curved termination made up of many basal planes not quite parallel to each other. The color of the material varies from pure white to deep brown, depending presumably on the amount of oxidation the manganese has suffered. The refractive index varies somewhat but is higher than that of pure brucite. The average values determined were: $\omega=1.59$, $\epsilon=1.60$. The following analysis by Bauer was made on light colored material and yields a Mg to Mn ratio of 5:1.. The Jakobsberg material has a ratio Mg:Mn of 7:1.

ANALYSIS OF MANGANBRUCITE FROM FRANKLIN

	PER CENT
H ₂ O	25.97
MnO	17.58
ZnO	3.56
MgO	49.94
CaO*	undet.
	97.05

*Present as CaCO₃

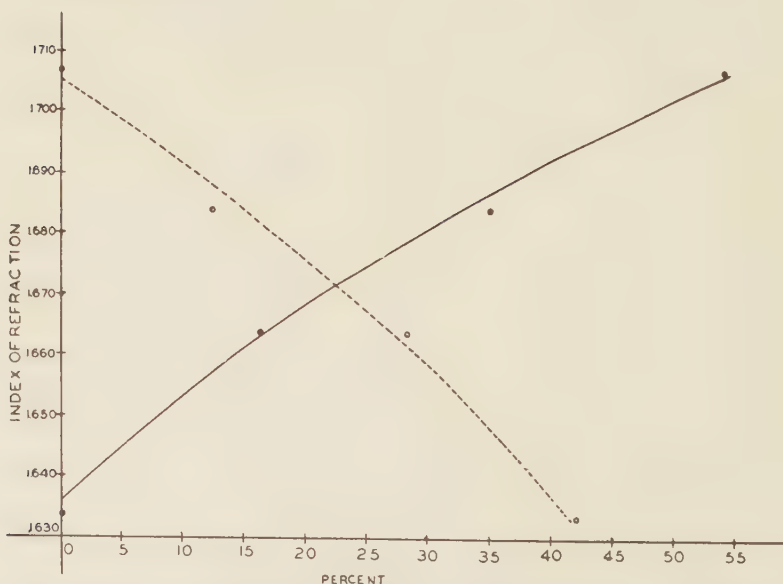


FIG. 4. Relations of refractive index and composition in the Apatite-Svabite series. Solid line, variation of refractive index (ω) with As₂O₅ content. Dotted line, variation of refractive index (ω) with P₂O₅ content.

IX. SVABITE

Many of the so-called apatites occurring in the ore at Franklin have been found to contain more or less arsenic replacing the phosphorus. All of the apatites embedded in the limestone, however, have been found to be free from arsenic. One of the highly arsenical varieties has been analyzed by Bauer and this analysis is given below.

ANALYSIS OF SVABITE			
	PER CENT	MOLECULAR RATIOS	
Insol.	0.29		
H ₂ O	1.32	.0733	.1104 = 1 × .1104
F	1.41	.0742	
CO ₂	trace		
CaO	45.89	.8195	.8788 = 10 × .0879
ZnO	1.54	.0189	
MnO	1.23	.0173	
MgO	0.84	.0208	
PbO	0.51	.0023	
As ₂ O ₅	35.24	.1532	.2415 = 3 × .0805
P ₂ O ₅	12.54	.0883	
	100.81		
Less O = F ₂	0.59	H ₂ O : F ₂ = 2 : 1	
	100.22		
Molecularly 36½ per cent. apatite.			
63½ per cent. svabite.			
G = 3.542		ω = 1.684	

TABLE I. VARIATION IN INDEX OF REFRACTION AND COMPOSITION IN THE APATITE-SVABITE SERIES.

	Percentage of		Index of Refraction (ω)	Specific Gravity
	Phosphate	Arsenate		
Apatite	42.3	0	1.634	3.20 ±
Apatite	28.4	16.2	1.664	3.446
Svabite	12.5	35.2	1.684	3.542
Svabite ⁵	0	54.4	1.707	3.54 ±

Another sample was partially analyzed for its arsenic and phosphorus content. The data for these intermediate members as well as the two end members, apatite and svabite, are given in table 1, from which a graph has been constructed (fig. 4) to show the vari-

ation in index of refraction with As_2O_5 and P_2O_5 in solid solution. The graph is not intended to be of great accuracy, since other factors such as fluorine, chlorine, CO_2 , and water have considerable effect on the optical properties. These have not been considered since the correlation data is not adequate. The graph is useful, however, in giving the approximate composition of any of the apatites found in the Franklin ores.

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PARAGENESIS OF THE NEWRY PEGMATITE, MAINE

H. J. FRASER, *Harvard University.*

The Dunton tourmaline deposit, which occurs in the town of Newry, Maine, has been known locally for a number of years because of the large tourmalines with pink centers and green or banded pink and green borders which it contains. The deposit is of additional interest mineralogically, not only because of the large crystals of spodumene and masses of amblygonite and pollucite which it contains, but also because of the varied and unusual mineral assemblage present.

The deposit has been briefly described by Bastin¹ and certain rare phosphates found there have been discussed by Palache.² The deposit was first opened during the summers of 1903 and 1904 in a search for gem tourmaline but, as the tourmalines were firmly embedded in their matrix, the difficulties of extracting the gems without shattering them were so great that the operations were abandoned. This quarry and others nearby were subsequently reopened during the summers of 1926 and 1927 under the superintendence of Mr. W. D. Nevel of Andover, Maine, in a search for commercial quantities of pollucite. Satisfactory quantities were obtained but mining has now ceased.

Due to the care with which Mr. Nevel collected all unusual minerals, it was possible to secure a very complete suite for the Harvard Mineralogical Museum. This suite formed the basis for the mineralogical data in this paper.

ACKNOWLEDGMENTS

The writer wishes to acknowledge his great indebtedness to Professor Palache whose constant assistance and constructive criticism were of the utmost value during the collection of the data and the preparation of this paper. Professor Palache made a crystallographic study of the tourmalines and constructed the figures given in this paper.

To Mr. H. Berman the writer is obligated for much assistance during the laboratory study of the minerals and the mineral sequence.

Mr. H. Butterfield visited and studied the Newry deposit in 1927 and the writer has drawn freely on his unpublished data.

LOCATION

The deposit is situated in the northeastern corner of the town of Newry, Oxford County, Maine. It occurs on the south side of the main highway which connects Andover and Rumford Point. A trail leaves the highway at a point 6.4 miles southeast of Andover and climbs westward about eight hundred feet to the quarry, which lies at an elevation of about 1525 feet above sea level and 4600 feet west of the main highway. Mining operations were confined to two outcrops, about 250 feet apart, which occur on the western side of the crest of the hill.

DESCRIPTION OF PEGMATITE

The wall rock surrounding the outcrops is a light green mica-schist composed essentially of muscovite, actinolite and quartz. This rock has been much disturbed so that near the outcrops, at least, the direction of schistosity is very variable. The schist has been penetrated by numerous pegmatite stringers of varying size which occur not only at the crest of the hill but also farther down on the slopes. The upper portion of the hill shows much pegmatite. The lower slopes near the main highway are composed principally of a quartz-mica-schist which is dark green in color.

Near the pegmatite contacts the schist has been altered with the development of mica, and the whole mass has been very extensively impregnated with tourmaline. This impregnation is especially evident on the hanging-wall side of the pegmatite. The distribution of the tourmaline crystals in the schist is very interesting. In many places the tourmalines are confined to very definite zones spaced at intervals of from three inches to several feet. These zones may run parallel for several tens of feet and in some places they definitely cut across the prevailing schistosity. The black tourmaline crystals occur oriented in all directions in the plane of a zone, but very rarely does one occur with its long axis at or near right angles to this plane. If the rock is broken parallel to one of these zones, almost a solid face of black tourmaline is exposed. Apparently the depositing solutions were very definitely guided along certain zones in the schist.

The pegmatite commonly has very sharp contacts with the schist. The dip and strike of the contact are very variable, but in general, the dip is steep, varying from 45° to 70°. The more southern of the two outcrops on which mining has progressed is roughly rectan-

gular in shape with a narrow arm running southward. The length north-south is about 160 feet and the greatest width is about 90 feet. The western contact is obscure, the others are very clear. Several schist pendants, with sharp contacts, occur in this quarry, and these together with the common sharp contact between schist and pegmatite and the abrupt changes in strike of the contact, which in places lies at right angles to its former course, clearly suggest that the pegmatite was forcibly injected along planes of weakness in the schist. This southern body which does not have any great lateral extent thus appears to be a pipe-like injection of pegmatite into the schist.

At the time of the writer's visit the footwall was so poorly exposed that little could be seen regarding banding in this area. Mr. Butterfield, who visited the quarry in 1927, reported that a layer of microcline about eight inches thick occurred along the footwall. Next to this was a zone of graphic granite, rather fine in grain, from five to eight feet thick and this graded into the central zone which contained the unusual and the precious minerals. No such banding may be observed on the hanging wall. Near the contact the graphic intergrowth is somewhat finer-grained and frequently there is a zone, always less than an inch in thickness, of black tourmaline just inside the contact. This tourmaline zone is very distinctly displayed in the northern quarry. The graphic intergrowth becomes much coarser towards the center of the pegmatite. It carries considerable quantities of lepidolite, the bunches of which become larger towards the center of the pegmatite. Spodumene and other lithia minerals tend to be concentrated in the central portion but their distribution is very irregular. Beyond a certain tendency for the unusual minerals to occur irregularly scattered through the central portion of the pegmatite and for the finer-grained graphic intergrowth of quartz and cleavelandite to occur near the contact, little indication of banding may now be observed in the deposit.

The northern pegmatite is more sill-like in form. The dip is around 50° east but varies considerably. The present excavation is about 100 feet long and 50 feet wide. The pegmatite outcrop continues to the north for some distance. The texture is coarser here than in the southern outcrop. Spodumene is present in large crystals, the largest recorded being ten feet long with a cross section of five by twenty-one inches. Amblygonite is especially abundant; one mass that was mined weighed nearly five hundred pounds.

There is no colored tourmaline here but in the southern pegmatite blue, green, red and zoned tourmaline occurs. Columbite is more abundant in the northern pegmatite but pollucite is apparently lacking. The uranium minerals occur mainly in this quarry. Otherwise the two pegmatite outcrops are similar.

MINERALOGY OF THE PEGMATITE

The following minerals were identified in an unusually complete collection of specimens, gathered in the main by Mr. W. D. Nevel and now contained in the Harvard Mineralogical Museum. In this paper a detailed description of the optical properties of the minerals is not given since most of the determinations were made on unanalyzed specimens. However, three rare phosphates from this locality which were of unusual interest, have been described together with analyses, by Palache.²

In the following paragraphs the minerals are arranged in the order of their approximate sequence, following Landes.³

Group 1 contains pyrite, black tourmaline, yellowish lepidolite, microcline and quartz. These minerals grade towards the center of the pegmatite into the group 2 zone which contains beryl (non-gem variety), apatite (high in manganese), red, green and blue tourmaline, microlite, columbite, cassiterite, quartz, mauve lepidolite, spodumene, cleavelandite and quartz. There is a minor break in the sequence at this point with some corrosion of the earlier formed minerals and a definite change in the composition of the minerals deposited. Then comes spodumene, pollucite, amblygonite and montebrasite, lithiophilite or triphylite, blue tourmaline, grey lepidolite and quartz.

At this point the sequence is definitely interrupted. There was extensive solution of the earlier formed minerals and the later minerals are characterized by a good crystal form and by deposition in vugs. These minerals, which constitute group 3, are albite, quartz, beryl (gem variety) green tourmaline (gem variety), beryllonite, rose quartz (in well-formed crystals), cookeite, siderite, eosphorite, francolite, herderite, reddingite, a red manganese phosphate and autunite. This marked the end of primary deposition.

Later percolating waters developed heterosite, manganite or other manganese oxides, chalcedony and opal, which together constitute group 4.

SIGNIFICANCE OF THE MINERAL SEQUENCE

The evidence indicating a separation of group 3 from group 4 is rather compelling, but that on which is based the separation of group 1 from group 2, and the subdivision of group 2, is not so convincing. The change from group 1 to group 2 is transitional, the transition being mainly one of texture, with the size of the constituent minerals increasing towards the center of the pegmatite. Such a transition may logically be expected since the later formed minerals and those formed in the central portion of the pegmatite were probably crystallized from a solution in which the proportion of water and other mineralizers was constantly increasing.

The fact that it is possible to arrange the minerals in a definite sequence suggests that the depositing solutions were undergoing continuous changes in composition. Before one mineral can replace another, the depositing solution must have undergone sufficient change in its composition or other conditions to permit the solution of the earlier formed mineral. Consequently the separation of a series of minerals into groups is really an indication of the degree of change in the depositing solution. If, however, this scheme were carried to the limit, every successive mineral would represent a successive group. Moreover many minor reversals of sequence are to be observed among the Newry minerals; quartz, for example, recurs many times in the general sequence. The recurrence of a mineral later in the general sequence is further evidence of fluctuations in the conditions of the depositing solutions and could hardly be considered as due, in all cases, to the ingress of fresh solution.

Group 3 stands very definitely delimited but its quantitative importance is small. The minerals comprising the group are either rare minerals, some of them being known in only a few other localities, or else they are minerals that have already been found in the sequence but here occur in unusually perfect crystals. It is doubtful if these minerals comprise as much as one per cent of the pegmatite. Their unusual nature or form excites much interest and, especially in a laboratory study, there is a tendency to overrate their quantitative importance, since in collecting one is always apt to gather the unusual and ignore the common minerals.

No new elements occur in group 3. The minerals are all characterized by their occurrence as crystals attached to the walls of solution cavities. It is difficult to estimate the time intervening

between the formation of the minerals of group 2 and group 3, but it seems most probable that this interval was short. It need be only of sufficient duration to permit the formation of solution cavities, a process which may be very rapid, and long enough to allow the solution to become again saturated so that the later minerals may be subsequently deposited.

The minerals of group 4 are products of alteration and consequently may have been formed at a much later date.

The available evidence indicates that the process by which the minerals of the three earlier groups were formed was continuous, the interval required for the solution of one mineral and the deposition of another being in most cases probably very short. It does not seem necessary to postulate the ingress of fresh supplies of solutions of different composition in order to produce the corrosion effects observed in this deposit. It is entirely possible that the quantitative composition of the solutions ascending from the source changed as time progressed, but the mineralogical evidence favors the idea that changes in the solution were brought about by deposition.

Certain minerals, for example lepidolite or quartz, recurred at numerous periods during the deposition. The frequent recurrence of these minerals probably indicates a local supersaturation of the solution with their constituents and not a bodily change of the solutions. The solution from which these minerals were precipitated, contained at least twenty-three elements. Conditions of equilibrium in such a solution must necessarily be nicely balanced and when the equilibrium is disturbed many minor adjustments, such as deposition of one constituent and re-solution of another, may be expected in the effort of the solution again to attain equilibrium. Numerous minor reversals in the general sequence of deposition are thus to be expected as a matter of course. But these minor variations should not, because of their greater local interest, be permitted to detract attention from the more general, yet orderly progress of deposition.

Warren and Palache⁴ found that there had been corrosion and replacement of the early minerals in the Quincy pegmatite; they believe that these pegmatites were formed by local segregations in the granite and consequently the replacement was probably accomplished by the same or similar solutions as those which deposited the earlier minerals.

The features shown in the Newry pegmatite are best explained by the assumption of a continuous process of deposition from ascending solutions which retained the same qualitative composition throughout the period of deposition.

DESCRIPTION OF THE MINERALS

GROUP 1

The minerals of this group constitute the ordinary pegmatite and therefore comprise the major portion of the deposit. They are, in order of deposition, pyrite, black tourmaline, lepidolite, microcline, and quartz. There is little doubt but what these minerals represent the earliest phase of pegmatitic deposition. Frequently it is the only phase exhibited. When more unusual minerals are present, they are commonly found in the interior of the pegmatite and both their position and their mode of occurrence is such as to suggest that they have formed at a later period.

The black tourmaline which is so well developed along certain zones of permeability in the schist, is included in this class although there is little evidence to prove that it was formed at this period rather than at some later date.

The minerals of this group are tightly intergrown with no interstitial spaces visible, except where there has been later solution activity.

Pyrite. The only pyrite seen was as inclusions in black tourmaline. It had a good euhedral form. It may have developed, due to excess of iron, in the course of the crystallization of the tourmaline.

Tourmaline. All of the tourmaline in this group is of the black variety. It generally shows good crystal forms, although the crystals are rarely large. Frequently this tourmaline occurs concentrated in a narrow band at the pegmatite contact. It also occurs scattered through the pegmatite and in the neighboring schists. It may show either a core or an internal layer of quartz.

Lepidolite. The lepidolite of this group has a yellowish color, sometimes closely resembling that of muscovite, but the minerals may be distinguished by means of a flame test. The lepidolite commonly has a subhedral form and occurs in bunches of from one-half to six inches in diameter.

Microcline. Microcline is quantitatively the most important mineral of this group. It often occurs in fairly large crystals, some of which are over a foot in length.

Quartz. Quartz is abundant, often occurring in masses equal to that of the microcline. Since in many places it was the last mineral to crystallize, it commonly occurs in anhedral forms, filling in and wrapping around the earlier minerals. It is commonly shattered.

MINERALS OF GROUP 2

The minerals placed in group 2 are those which give the distinctive character to the Newry deposit. They include highly colored minerals and some are in large and well formed crystals; all are tightly intergrown without interstitial spaces. They are marked by the increasing importance of the alkali elements sodium, lithium and caesium, and there is definite evidence of replacement of earlier minerals with sequence quite clearly displayed.

The change that occurred in the composition of the solutions during the time that this group was being deposited appears to have been so gradual that there was no definite break either in the sequence or composition of the minerals. However, the widespread development of cleavelandite and quartz which preceded the main deposition of the lithium minerals seems to indicate a transitional period at that time.

Tourmaline. In some respects the most notable mineral in this deposit is lithia tourmaline. Crystals up to a foot and more in length and three or four inches through are tightly frozen in the pegmatite; deep pink in the center, the outer coating is generally light green and this vivid coloring and rounded, triangular outline made them striking objects, especially in the quarry openings. The tourmaline is at times uniformly colored, pink or clear green throughout and such crystals, although imbedded in quartz or spodumene, may sometimes be extracted with distinct termination. In parts of the pegmatite the tourmaline is light to dark blue in clear transparent crystals generally enclosed in quartz or amblygonite. It would appear that such crystals were attached at one end and grew out into an open space or a liquid-filled cavity. The tourmalines are often replaced by later minerals. In several specimens a layer of lepidolite was formed around a tourmaline crystal and in one specimen there were several alternating layers of lepidolite and quartz around a tourmaline crystal.

Another phase of green lithia tourmaline is in slender needles intergrown between the leaves of books of mica both muscovite and lepidolite or in radiating "sun-bursts" in cleavelandite. These are

certainly later than the mica for in one case a mica crystal, fractured by movement of the rock, showed a tourmaline traversing the open crack.

Still another phase of tourmaline is widely distributed at Newry. It is opaque and granular of a bright blue color and always appears as borders about triphylite or in veins cutting it. It is clearly replacing the phosphate. Whether it is formed before or after the associated siderite could not be established.

The evidence is clear that lithia tourmaline in one form or another was being deposited from the beginning to the end of the formation of the minerals of Group 2.

Beryl. The beryl of this period is in coarse crystals with a tabular habit parallel to the basal pinacoid. They are of moderate size, up to five inches in diameter, pale green to greenish white in color and opaque. The high indices of refraction are suggestive of caesium beryl.

Apatite. Apatite is rare and the specimens found were poorly crystallized. The high indices and green color of the apatite suggest that it contained considerable manganese.

Microlite. Microlite is commonly present as well formed octahedrons in cleavelandite. The color varies from yellow to dark brown. In places the crystals are fairly large octahedrons, up to three-fourths of an inch in diameter. Spectroscopic analyses by Mr. Gedney have indicated the light yellow colored mineral is microlite and the dark brown mineral pyrochlore.

Cassiterite. A few crystals of cassiterite were found commonly imbedded in cleavelandite.

Columbite. Columbite is present in two distinct generations. The first generation occurs in excellent crystals and is definitely earlier than the cleavelandite. Some of these crystals reach a maximum of four inches in length. The second generation, chiefly mangano-columbite, is formed as platy masses, intergrown with or replacing cleavelandite or intersecting tourmaline. Sometimes the columbite is seen as flat thin crystals formed between the lepidolite "books."

One crystal was secured which showed a termination projecting into an opening in cleavelandite. This was measured by Mr. Berman and is shown in figure 1. It is a very complex combination, tabular parallel to the front pinacoid. (The drawing and symbols are in the position of Schrauf and Goldschmidt, not that of Dana.)

It shows the forms $c(001)$, $a(100)$, $b(010)$, $g(110)$, $m(130)$, $z(150)$, $d(170)$, $k(011)$, $l(012)$, $f(032)$, $e(201)$, $u(111)$, $n(211)$, $s(221)$, $\pi(231)$, $\beta(121)$, $o(131)$.

Mica. Both muscovite and lepidolite occur in the Newry pegmatite in broad plates, although the first is much the more common. Plates of lepidolite up to eleven inches broad, shot through with green tourmaline were abundant in one quarry. In addition there

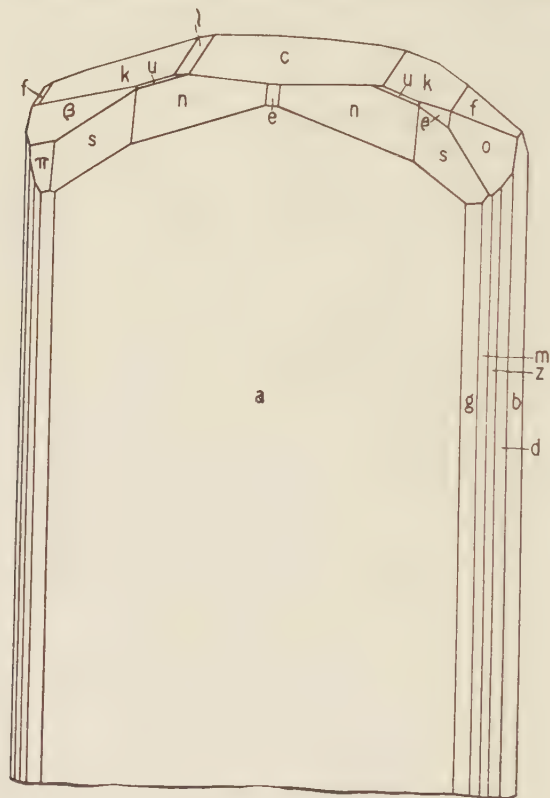


FIG. 1. Manganocolumbite, Newry, Maine.

are two generations of coarse-to-fine-grained lepidolite. The earlier is mauve in color and frequently encloses amblygonite, spodumene, tourmaline and other minerals and is in turn included by still later ones. The later generation is grayish in color and appears to be considerably later than the cleavelandite. It has been suggested that the gray lepidolite contained rubidium but this has not been confirmed.

Cleavelandite. Cleavelandite, the platy variety of albite, is one of the commonest minerals of this group and makes up a large part of the deposit. It sometimes occurs in large masses and has extensively replaced the earlier minerals which now appear as inclusions in it.

The color of the cleavelandite varies from a dull white to a pale blue. Some of the dull, opaque cleavelandite appears to have been much altered and all of the cleavelandite was very susceptible to the later solution corrosion. Often the cleavelandite is colored brown to black by manganese stains, and many small pockets and solution cavities have been developed in it. The later pocket-occurring minerals are frequently formed in these cavities, thus giving rise to an apparent association between the cleavelandite and these minerals.

Quartz. The quartz of this class is generally anhedral and is commonly intergrown with cleavelandite. In places however, group 2 quartz may show good crystal forms, but it then appears to belong to a slightly later period of deposition.

At this point in the sequence of group 2, there appears to be a minor break in the continuity of deposition. The later minerals are commonly of unusual composition. Their order of sequence is not, in all cases, as definite as that of the earlier minerals. The majority of these minerals were definitely later than the cleavelandite but there was some overlapping.

Spodumene. Spodumene is one of the most characteristic minerals of this group. It is commonly developed in large masses and often in good crystals. In the northern pegmatite some of the crystals were over ten feet in length. A structure not before recognized in spodumene was shown by a large crystal fragment. A series of bands traverses the cleavages much as pericline twin lamellae appear in plagioclase. The bands are one or two mm. wide, fairly even but interrupted, sometimes gently curved. Their general attitude in the block is nearly parallel to the basal pinacoid. That they are due to twinning of some sort is certain but the law was not determined. There is no sign of alteration in the spodumene.

Spodumene very commonly encloses mauve lepidolite. Sometimes it is earlier than cleavelandite, sometimes they appear nearly contemporaneous, but the bulk of the spodumene was probably formed after the lepidolite.

Pollucite. Locally pollucite is fairly common. It occurs closely associated with spodumene and in such a manner as to appear to be

replacing it. Pollucite is commonly found in fractured masses, the fractures being filled with a dull white variety of chalcedony. This association is so general in this deposit that it can often be used as a criterion to distinguish pollucite from quartz. The occurrence of pollucite at Newry has been briefly described by Fairbanks⁵ who reported that lepidolite and caesium-beryl were the best indicators of the presence of pollucite at Newry.

Amblygonite and Montebrasile. These two minerals are developed rather locally, although they may occur in very large masses. Commonly they show good crystal form. They often enclose cleavelandite and other earlier minerals and sharp crystals of amblygonite are found in massive lepidolite. The distinction between amblygonite and montebrasile is based chiefly on the difference in their optical properties.

Triphylite. This mineral is abundant and very noticeable in the pegmatitite. Areas from a few inches to a foot across were seen showing the good cleavage characteristic of this mineral. It is white to pale blue in color when fresh. It is generally surrounded by a border of bright blue massive tourmaline which also forms veins and irregular replacement areas in the triphylite. Some of the crystals are also marked by the brilliant purple coating of heterosite (purpurite) to which it has altered. Mixed with the tourmaline and clearly also a replacement is light brown granular siderite.

Sphalerite. Sphalerite occurs in small quantities at Newry. It is enclosed and replaced by massive blue tourmaline.

Pitchblende. Pitchblende has been found in small amounts at Newry. It is largely altered to colored crusts—orange gummite and lemon yellow autunite, the latter strongly fluorescent with a green color under the spark gap. In one specimen pitchblende is in immediate contact with cassiterite.

MINERALS OF GROUP 3

These minerals are all developed in pockets and hence their position in the classification is readily ascertained.

Albite. The albite of this class occurs as very well-formed crystals attached to the walls of cavities. It thus differs in form from the earlier, platy variety, cleavelandite. With the albite are found good quartz crystals.

Beryl. The beryl of this type is the gem variety. It is found in excellent crystals, often well terminated. Its color is green, it is transparent and sometimes free from flaws.

Tourmaline. The tourmaline of this group is of gem quality, generally green or blue in color and showing good crystal form. Several of these crystals were measured and showed the forms: $m(10\bar{1}0)$, $a(11\bar{2}0)$, $r(10\bar{1}1)$, $\epsilon(10.0.\bar{1}0.1)$, $o(02\bar{2}1)$, $\beta(09\bar{9}2)$, $x(12\bar{3}2)$, $v(13\bar{4}1)$, $t(21\bar{3}1)$, and $u(32\bar{5}1)$. The two distinct habits are shown in the figures. No. 2 is a dark blue crystal characterized by the large faces of the steep positive rhombohedron. No. 3 is a clear green color and shows two negative scalenohedrons developed in perfect symmetry. Other crystals of this type also show in addition

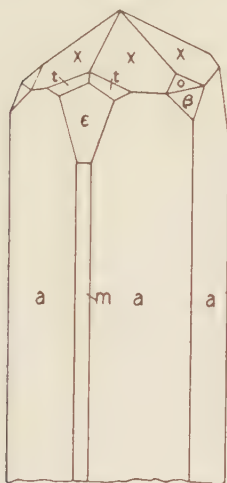


FIG. 2.

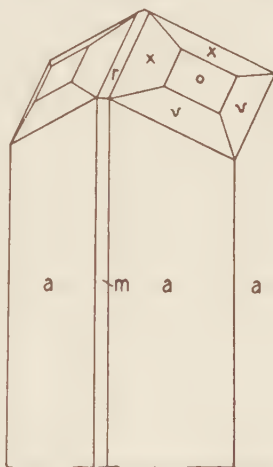


FIG. 3.

Tourmaline, Newry, Maine.

two positive scalenohedrons. Crystals of tourmaline such as these have been found at many of the Maine pegmatite localities but seem never to have been figured. It seemed therefore worth while to place these on record. Sometimes small radiating masses of blue-green tourmaline crystals are formed on quartz or albite crystals and project out into open spaces. These radiating tourmalines are to be distinguished from the earlier, fibrous solution remnants. In one place a group of the later was seen joining above and below to the original tourmaline crystal. Apparently these fibres represent less soluble parts of the original crystal.

Beryllonite. The fresh mineral is white and shows perfect basal cleavage and less perfect orthopinacoidal cleavage. The crystals, which are up to 3 inches in diameter, are generally attached to

cleavelandite although rarely they are attached to the wall of a cavity. In places the crystals include early minerals, notably green tourmaline.

The beryllonite is often altered and stained with manganese. The alteration varies from a coating of herderite to complete destruction of the crystals and the development of a cavity or a pseudomorph. As the material alters it sometimes develops a fibrous structure parallel to the vertical axis. An analysis together with the optical properties of this mineral has been published by Palache and Shannon.²

Cookeite. In some places there has been formed a white, micaceous mineral whose optical properties are close to those given for cookeite. This mineral is commonly seen coating the other pocket minerals and also some of the earlier minerals. In places it appears as an alteration product after cleavelandite.

Siderite. The presence of siderite in this group is somewhat doubtful, it may belong to a later period. It is present as well formed crystals, and commonly is altered to limonite.

Rose Quartz Crystals. The occurrence of rose quartz in well formed crystals is not common. It is present at Newry in excellent crystals which are fastened on to the wall of the cavities and project out into the open spaces. The crystals consist of a six-sided prism, up to three-eighths of an inch in length, with six pyramidal faces. Generally the crystals are very closely spaced. Francolite and herderite have been deposited on these quartz crystals.

Eosphorite. Eosphorite is one of the commonest phosphates at Newry. It occurs as a pocket mineral, sometimes formed on quartz crystals in the open cavities, sometimes as a fan-shaped aggregate on albite and occasionally it may be seen cutting across beryllonite crystals. The color varies from opaque brownish black to a transparent light brown and almost to a yellow. It seems probable that there is a considerable variation in the manganese and iron content and that the darker colored material from the northern pegmatite approaches childrenite in composition. The eosphorite crystals are of the same habit as those of Buckfield, a pyramid combined with front and side pinacoids. Its analysis and optical properties are given by Palache and Shannon.²

Francolite. Francolite occurs as light-colored radiating masses on albite, quartz and other crystals. It is sometimes stained a dark brown by iron and manganese solutions. Francolite is common but

the radiating masses seldom exceed an eighth of an inch in diameter.

Herderite. Herderite commonly occurs in this deposit as small "gum drop" masses varying in color from yellow to black. The color variation is probably due to staining by impurities. The "drops" of herderite are commonly perched on albite, quartz, francolite or other crystals. It may also occur in considerable quantities as a botryoidal coating lining cavities or coating beryllonite crystals. The coating on the beryllonite is evidently an alteration product, but the other occurrences have definitely been formed from solutions. It is one of the last minerals to be formed. While it is not an uncommon mineral in the pegmatites of this region, its occurrence in these radial fibrous forms is unusual. Palache and Shannon² have published an analysis of this species.

Reddingite. On one specimen a reddish brown mineral was observed as a radial fibrous deposit on herderite. The optical properties of this mineral were near those given for reddingite and the mineral gave a good microchemical test for phosphorus. From these data it was concluded that the mineral was reddingite.

Unknown Red Manganese Phosphate. On several specimens a reddish brown mineral occurred on the herderite and elsewhere. This mineral was in small radiating needles. It has been described by Landes³ and the mineral from Newry as very similar in appearance to that from Buckfield. It occurs in such minute quantities that its identification is extremely difficult.

MINERALS OF GROUP 4

These minerals are the result of supergene processes. One striking feature of this period is the extensive development of a brown or black manganese stain. Among the minerals of this group are manganite and other manganese oxides which probably have developed by alteration of the earlier minerals. Limonite has developed in places, probably from the decomposition of siderite. Heterosite has formed by the alteration of triphylite. Chalcedony has formed in and around pollucite. Locally, opal has deposited on quartz crystals.

CONCLUSION

The pegmatite at Newry fails to show any noteworthy banding or zoning of its constituents. A detailed examination of the mineral sequence however, shows that there is a rather close parallelism,

mineralogically, with the pegmatites at Buckfield and elsewhere, as described by Landes. From the structural and textural data available there appears to be sufficient evidence to show that there were at least three definite periods during the formation of the pegmatite. The first and second periods were transitional but the second and third periods were definitely separated by a period of extensive replacement activity which however was very local in its action. The evidence indicates that the entire process was essentially continuous.

During the first period the solutions deposited mainly silicates; the second period began with the deposition of silicates, and then changed to lithium silicates and phosphates; the third period was one of deposition of manganese, iron, aluminum, and beryllium phosphates. After the main period of deposition had ceased, supergene processes became effective to a slight extent.

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CRYSTALLOGRAPHY OF STIBNITE AND ORPIMENT FROM MANHATTAN, NEVADA

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A collection of the arsenical ores of the White Caps Mine at Manhattan, Nevada, secured for the Harvard Mineralogical Museum from H. G. Clinton, contained well crystallized stibnite and orpiment. The study of these crystals has added to our knowledge of the crystallography of these minerals and is therefore presented here in some detail. The geology of the district has been described by Ferguson.¹ The ores occur as replacement deposits in a Cambrian limestone.

STIBNITE

The following quotation from Ferguson describes the various modes of occurrence of stibnite in the White Caps Mine.

"Stibnite is found throughout the deposit, but is more prominent in the western part of the mine. Small crystals are frequently found in the vugs of the dark quartz. Its most usual occurrence is in roughly radiate crystalline masses, in places several inches in diameter, which replace the limestone or coarse calcite, or more rarely the dark quartz. In places small 'sunbursts' of stibnite crystals occur along cleavage planes of the coarse calcite and small needles were found in the fault gouge of the later faults. In all these positions, particularly in the eastern ore body, stibnite may be closely intergrown with realgar. A rare occurrence of stibnite is in the form of delicate hair-like crystals found in cavities in the calcite and rarely in the quartz. Orpiment is found in this same habit and association, but not realgar. Although the stibnite is practically barren of gold it is confined to the ore bodies. Only rarely do small clusters of stibnite crystals occur outside of the mineralized areas."

Specimens of all these types of occurrence are in the collection studied. The best crystals came from vugs in quartz.

The measured crystals are generally small, ranging from hair-fine needles to stout peg shapes up to two or three millimeters diameter. Many crystals in the vugs are distorted and twisted so that the faces are warped. There is little alteration visible; on some there is a delicate iridescent film which rarely destroys the reflecting power of the crystal faces.

The crystals are of three principal habits:

- (a) very slender needles with simple terminations, Figure 1.
- (b) stouter crystals with simple terminations dominated by a new orthodome (503) very characteristic for the locality. Figure 2 and figure 4.



FIG. 1. Stibnite.

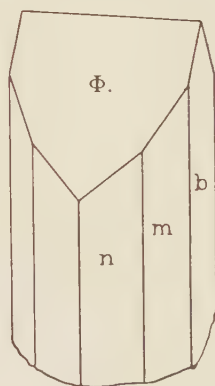


FIG. 2. Stibnite.

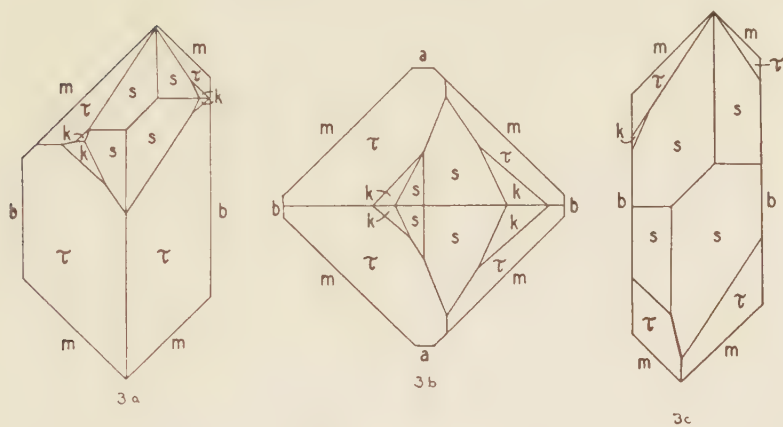


FIG. 3. Stibnite.

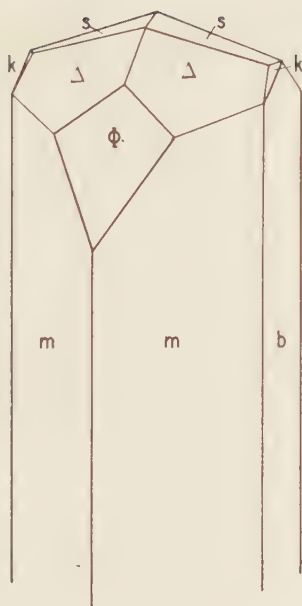


FIG. 4. Stibnite.

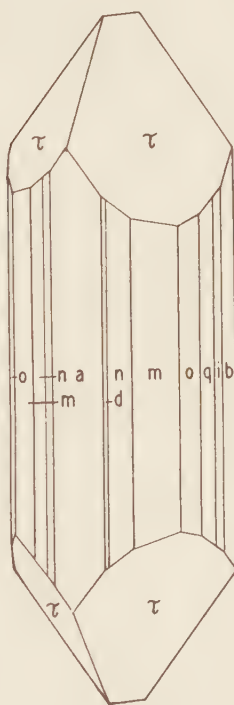


FIG. 5. Stibnite.

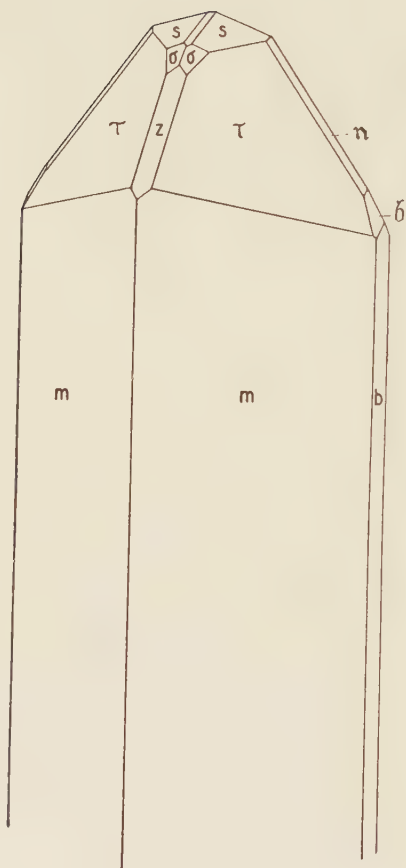


FIG. 6. Stibnite.

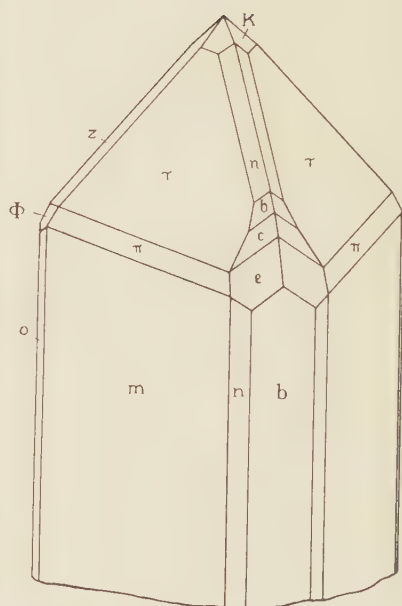


FIG. 7. Stibnite. Drawn with side pinacoid in front.

(c) short crystals with more or less complex pyramidal terminations. These are very similar in habit to the average crystals from Ichinokawa, Japan. They are shown in figures 3, 5, 6, and 7.

Thirty-three crystals were measured, some of them by both authors, and revealed a very complex form series with three well established new forms. Since the crystallography of stibnite has been very carefully studied recently by Neff³ there seemed to be no occasion for a general discussion of the form series here. A list of the forms observed is given in the following table together with a table of combinations.

1. TABLE OF THE FORMS OF STIBNITE FROM MANHATTAN, NEVADA.
List of Forms:

Letter	Symbol	Frequency	Letter	Symbol	Frequency
<i>b</i>	(010)	Every crystal	<i>p</i>	(111)	2 crystals
<i>a</i>	(100)	3 crystals	<i>s</i>	(113)	20 crystals
<i>d.</i>	(12.1.0)	4 "	μ	(114)	1 "
<i>h</i>	(310)	1 "	<i>v</i>	(227)	1 "
<i>n</i>	(210)	14 "	η	(116)	3 "
<i>i</i>	(320)	4 "	<i>K</i>	(233)	24 "
<i>k</i>	(430)	1 "	λ	(313)	1 "
<i>m</i>	(110)	Every crystal	τ	(343)	21 "
<i>d</i>	(230)	7 "	η	(353)	1 "
<i>o</i>	(120)	12 "	σ	(213)	10 "
<i>q</i>	(130)	14 "	<i>n</i>	(243)	13 "
<i>i</i>	(140)	6 "	<i>b</i>	(253)	14 "
θ	(160)	1 "	<i>t</i>	(263)	4 "
Θ	(170)	1 "	<i>c</i>	(273)	10 "
<i>l.</i>	(180)	1 "	<i>e</i>	(283)	2 "
<i>N</i>	(023)	3 "	<i>x.</i>	(293)	3 "
<i>L</i>	(103)	3 "	ψ	(146)	1 "
<i>z</i>	(101)	10 "	<i>e</i>	(123)	10 "
* Φ .	(503)	22 "	<i>M</i>	(413)	1 "
			Ξ	(5.11.3)	1 "
			<i>m</i>	(5.10.3)	3 "
			<i>T</i>	(521)	1 "
			$\phi.$	(4.10.3)	1 "
			α	(9.10.3)	4 "
			* Π .	(673)	7 "
			* Δ .	(425)	6 "

* indicates new form.

2. TABLE OF COMBINATIONS.

1. b, m, s, τ . Slender needles. Figure 1.
2. b, n, m, Φ . Figure 2.
3. b, m, τ, \bar{b} .
4. b, m, s, K, τ . Figure 3, a, b, c .
5. b, m, Φ, s .
6. b, m, Φ, s, K, Δ . Figure 4.
7. $b, m, \Phi, s, K, \tau, \sigma$.
8. $b, n, i, m, \Phi, s, K, \Pi$.
9. $b, d, n, i, k, m, q, \tau$.
10. $b, m, \Phi, s, K, \tau, e$.
11. $b, a, d, n, m, o, q, i, \tau$. Figure 5.
12. $b, m, d, o, q, K, \tau, \bar{b}$.
13. $b, m, \Phi, K, \sigma, n, \bar{b}, c$.
14. $b, m, L, z, s, \tau, \sigma, n, \bar{b}$. Figure 6 approximately.
15. $b, n, i, m, z, \Phi, K, \tau, s, \sigma, n, t, e, \bar{b}, m$.
16. $b, n, m, o, q, z, \Phi, K, \tau, n, T, M, e, a, \bar{b}, \Pi, c$.
17. $b, a, d, n, m, o, q, i, \tau, n, c$.
18. $b, m, q, i, \theta, \Theta, z, p, K, \tau, n, \bar{b}, t, c, x, m$.
19. $b, m, d, o, q, L, z, \Phi, N, s, \mu, v, \bar{b}, K, \sigma, n, \bar{b}, c, x, e, \Pi$.
20. $b, n, m, d, o, q, i, z, \Phi, s, k, \tau, \sigma, n, \bar{b}, t, e, a, \Pi$.
21. $b, m, d, o, q, z, \Phi, K, \tau, n, \bar{b}, c, x, e, a, \Pi$.
22. $b, a, d, n, i, m, d, o, q, i, l, N, p, s, K, \lambda, \tau, \eta, n, \bar{b}, c, x, \psi, e, \phi$.
23. $b, n, m, q, L, z, \Phi, N, s, \bar{b}, K, \tau, \sigma, n, \bar{b}, t, c, \phi, \Pi$.

There are doubtless other particular combinations of the many forms present. It will be noted that the prism series is very rich in forms. The new orthodome (503) is present on two-thirds of the measured crystals and gave excellent readings in good position. The two new pyramids, although not so constant in position, were present on so many crystals that they are regarded as well established. The measurements for the new forms are as follows:

	CALCULATED		MEASURED		No. OF		LIMITS	
	ϕ	ρ	ϕ	ρ	FACES	CRYSTALS	ϕ	ρ
(503)	90°00'	59°40'	90°00'	59°40'	15	10		59°36'–59°47'
(673)	40°48'	72°19'	40°53'	72°24'	11	7	40°35'–41°11'	72°05'–72°40'
(425)	63°36'	42°29'	63°36'	42°13'	11	5	62°37'–62°25'	41°31'–42°39'

Of the many pyramids the most prominent is τ (343) which appears in all the drawings and is present on two-thirds of the

crystals. As this form is also the dominant form on the stibnite of Japan, there is a striking similarity between the crystals from the two localities. Indeed the whole form series of the Manhattan stibnite shows a distinct parallelism to that of Japan. Had the more complex crystals been drawn, such as combinations 18 to 23, the similarity would be still more striking. In view of the many crystal figures of the Japanese stibnite now available it was regarded as a waste of labor to draw all of these crystals, only one of which, No. 16, has been attempted.

Figure 3 was drawn to show how various may be the appearance of crystals of stibnite on which identical forms occur but with varying and unequal development of their faces. It is impossible to recognize the forms except by measurement.

In addition to the forms regarded as typical, almost every more complex crystal had single faces to which more or less definite and simple indices could be assigned but as they were quite sporadic the data is not presented.

It appears that the stibnite crystals from Manhattan may be placed along with those from Felsöbanya and Japan as representing this mineral at the maximum of crystal development.

ORPIMENT

Orpiment occurs very abundantly at the White Caps Mine, chiefly in massive form or replacing realgar. It was found very rarely in vugs of calcite in the form of isolated crystals. These were in some cases slender needles of a clear golden yellow color and in others in stout crystals with definite terminations. As is usually the case with this mineral, most of the crystals were bent and bruised but a small number of uninjured crystals was removed and measured. As they add definite proof to that already advanced that orpiment is monoclinic, the data are presented. Furthermore an angle table is given for orpiment, regarded as monoclinic, since none for two-circle measurements has hitherto been printed.

The only modern descriptions of orpiment crystals are those of Stevanovic⁴ and Farrington.⁵ Both authors regarded the mineral as monoclinic and gave figures. In some respects the crystals from Mercur are similar to those here studied.

Ten crystals were measured, most of them fragmentary or so intergrown with other individuals that only a part of their faces were accessible. The perfect pinacoidal cleavage and the excellent

development of the prism zone made orientation always definitely possible. In some cases the measurements were made by orienting the crystal with (010) as pole. In these cases only interfacial angles



FIG. 8. Orpiment, Manhattan, Nevada, drawn from back.

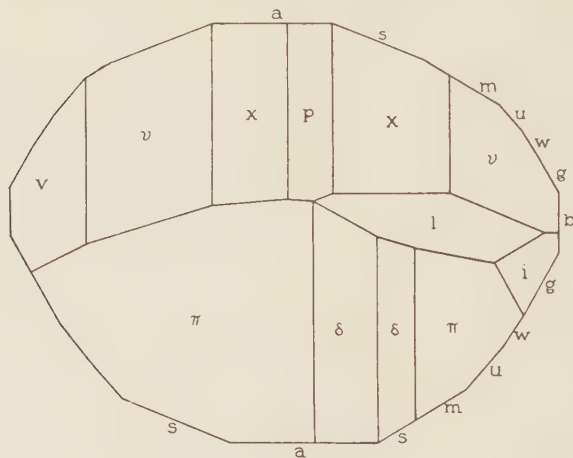


FIG. 9. Orpiment.

were obtained and although these sufficed to identify the forms they are not included in the angles tabulated below. There are three striated zones on the crystals more or less well developed.

The distinction between these zones is not easy and it is largely this character that has given rise to the doubt as to whether orpiment is orthorhombic or monoclinic. It was found possible to distinguish them, however. The prism zone [001] has distinct plane faces with better lustre and surface than either of the others and striations are not deep. The zone of positive pyramids [10 $\bar{1}$] and of negative pyramids [101] are similar; both are deeply striated but the signals reflected from the front series [101] were much less numerous than those from the back ones. In addition to these three zones the only faces on our crystals were the clinodome l(023) and the positive pyramid i(243). The measurements obtained were not sufficiently good to permit the calculation of reliable axial elements. The calculated angles given in the following table are therefore based on the elements of Stevanovic.

TABLE III
FORMS AND CALCULATED AND MEASURED ANGLES OF ORPIMENT FROM MANHATTAN

Let- ter	Sym- bol	Calculated		Measured				No. of measured		No. of crysts. on which seen
		ϕ	ρ	ϕ	Limits ϕ in minutes	ρ	Limits ρ in minutes	faces	cryst.	
<i>b</i>	(010)	0° 00'	90° 00'	0° 00'	0' to -33'	90° 00'	—	6	4	10
<i>a</i>	(100)	90 00	90 00	90 20	0 to -42	90 00	—	3	2	4
<i>s</i>	(320)	68 19.	"	68 07	+12 to -12	"	—	3	2	6
<i>m</i>	(110)	59 12	"	59 16	+47 to -34	"	—	5	4	7
<i>u</i>	(120)	39 59	"	39 49	+26 to -28	"	—	9	5	8
<i>*w</i>	(250)	33 51.	"	33 44	+ 1 to - 1	"	—	2	2	3
<i>g</i>	(130)	29 13	"	29 23	+ 4 to - 5	"	—	6	5	7
<i>l</i>	(023)	1 32	23 55.							1
<i>*o</i>	(101)	90 00	48 25.	92 40		48 52		1	1	2
<i>c</i>	(103)	"	20 59.							
<i>d</i>	(103)	-90 00	19 48							
<i>p</i>	(101)	"	47 49	-89 40		47 49		1	1	2
<i>q</i>	(449)	-58 34	29 33							
<i>r</i>	(212)	-73 14	49 03.	-76 56		48 52		1	1	1
<i>x</i>	(323)	-68 07	49 56.	-68 22	+37 to -37	49 57	+16 to -14	5	3	6
<i>y</i>	(343)	-51 13	54 46	-51 43	+71 to -98	55 08	+72 to -99	6	4	8
<i>β</i>	(232)	-47 53	56 05							
<i>y</i>	(585)	-46 03	56 53	-46 11		58 25		1	1	1
<i>v</i>	(121)	-39 41	59 57	-39 41		61 27		1	1	4
<i>*f</i>	(252)	-33 34	63 23	-33 59		65 33		1	1	2
<i>*α</i>	(131)	-28 57	66 19	-32 14	+71 to -70	66 10	+10 to -11	2	2	2
<i>*δ</i>	(414)	81 37	48 44	82 23		48 56		1	1	3
<i>*π</i>	(313)	78 52	48 58	76 56	+13 to -17	48 32	+44 to -31	3	3	4
<i>*μ</i>	(212)	73 34	49 36	74 16	+39 to -56	49 22	+22 to -58	4	3	6
<i>i</i>	(243)	40 26	49 21	41 48		50 03		1	1	3
<i>k</i>	(123)	-39 04	29 44							
<i>n</i>	(133)	-28 25	37 06							
<i>z</i>	(523)	76 41	62 33							
<i>κ</i>	(423)	-73 16	57 01							

* Indicates new form.

The elements on which the angles were calculated are as follows:—

$$\begin{aligned} a:b:c &= 0.5962:1:0.6650. & \beta &= 90^{\circ}41' \\ p_0 &= 1.1154, & q_0 &= 0.6650. & \mu &= 89^{\circ}19' \end{aligned}$$

The agreement of calculated and measured angles is not good but it is at least as good for the forms indicated in the table as new as for those already established.

The two figures drawn give an inadequate representation of the crystals which are much distorted by unequal growth of the faces. Figure 8 shows a common habit—plates with an acute summit where prism zone meets negative pyramid zone. This crystal is drawn as seen from the back. Figure 9 is a basal projection of the largest crystal, measuring about 1 cm. in width and height. It was not completely bounded by the prism zone but the prisms found on it have been restored.

A further evidence of the monoclinic character of orpiment was obtained by carefully measuring the extinction direction in orientated cleavage plates. It was found that Y to c made an angle of from one to three degrees with an error of less than one-half degree, in the negative quadrant. The extinction was not parallel in any of the five cleavage flakes examined.

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PEGMATITE MINERALS OF POLAND, MAINE

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In 1911, Professor Palache visited the Berry quarry at Poland, Maine, already long abandoned. He found there a small group of specimens which had been taken from this quarry, but concerning the relative occurrence of which nothing could be learned. In them were noted a number of rare phosphates first found at Branchville, Conn., and up to that time not found elsewhere. These phosphates have, however, now been found at Newry, Maine, and Buckfield, Maine, but since they are still rare a description of them seems worth while. One of them, eosphorite, has been completely described¹ by Dr. Drugman who had separated the other minerals of the group for analysis and had begun their study but never completed it on account of the outbreak of the war. The specimens were subsequently returned to Harvard where the study was resumed by the authors.

The chief information concerning this locality is contained in Bastin's well-known account of the Maine pegmatites² from which we here abstract a short description of the quarry.

The Berry quarry is located in the town of Poland, across the Little Androscoggin River from Mt. Apatite. It was at no time worked extensively, the quarry consisting mainly of a few scattered openings in the pegmatite ledge. The main mass of the pegmatite is essentially like that of Mt. Apatite, across the river, *i.e.*, a graphic intergrowth of quartz and microcline with some orthoclase. Other minerals of the solid pegmatite reported by Bastin are: muscovite, biotite, albite, beryl and amblygonite. Pocket minerals reported by Bastin are: lepidolite, vari-colored gem tourmaline, herderite and lavender colored apatite. In addition to Bastin's list must be mentioned alkali-beryl, the so-called pocket beryl, which is said to contain caesium. A handsome crystal of this type of beryl from this quarry is in the Harvard collection.

The Berry quarry has also been mentioned by Landes in his paper on the pegmatites of the region.³

¹ Drugman, J. On childrenite from Crinnis Mine, Cornwall, and Eosphorite from Poland, Maine, *Min. Mag.*, **17**, 81, 1915, pp. 193-201.

² Bastin, E. S. Geology of the Pegmatites and Associated Rocks of Maine, *Bull.* **445**, U. S. G. S., 1911.

³ Landes, K. K. The Paragenesis of the Granite Pegmatites of Central Maine, *Am. Mineral.*, **10**, 1925, pp. 355.

The minerals here described are of a later stage in the mineralization of the pegmatite than those of Bastin's list and are especially interesting in that they represent an uncommon period in the paragenesis of lithia pegmatites. Landes has referred to this phase at Buckfield as the intermediate hydrothermal stage.

GENERAL DESCRIPTION OF THE SPECIMENS

The half dozen specimens studied consisted of buff colored microcline much stained by manganese oxide, in which are small pockets of the later minerals. These pockets, about 3 or 4 inches in largest dimension are rimmed by a narrow band of amblygonite, approximately a half inch wide, next to the feldspar. Within this band is a somewhat wider irregular layer of rhodochrosite with numerous small cavities into which project small etched crystals of the same mineral. Cutting the rhodochrosite are small veinlets made up of small doubly terminated quartz crystals. These veinlets form a network in the inner portions of the pockets, from which the rhodochrosite has been partially removed by the solutions which later deposited the phosphate minerals. Manganese oxide, a late product of alteration, stains or coats almost all the cavity minerals as well as the adjacent microcline.

PARAGENESIS OF THE PHOSPHATE MINERALS

The sequence of events leading to the deposition of the cavity minerals seems to be somewhat as follows. The feldspar was replaced first by amblygonite, which may have filled the entire pocket. Then manganese rich solutions replaced the greater part of the amblygonite with rhodochrosite which in turn was cut by veinlets of quartz. Later manganese solutions attacked the rhodochrosite leaving central cavities in the pockets into which were introduced the manganese phosphates, eosphorite, reddingite, dickinsonite and fairfieldite, followed by apatite. Last of all supergene alteration changed the reddingite to landesite; and a general manganese staining was the final step.

It is probable that the lithiophilite, of which there was a single large cleavage block was formed at about the same time as the amblygonite, and had filled a pocket in the microcline.

The following list gives the probable sequence of the minerals occurring in the pockets:

Amblygonite
 Lithiophilite
 Rhodochrosite
 Quartz
 Eosphorite
 Reddingite
 Dickinsonite
 Fairfieldite
 Apatite
 Landesite
 Yellowish brown globules
 Manganese oxide

DESCRIPTION OF THE MINERALS

AMBLYGONITE

The amblygonite forms a tough compact rim around the pockets and grades into the feldspar which it undoubtedly replaces since remnants of the feldspar are found remaining in the amblygonite. There is a peculiar green stain in some portions of the amblygonite for which an explanation has not been found. The amblygonite was identified optically.

LITHIOPHILITE

The single specimen of lithiophilite studied was a cleavage block, associated with reddingite, which replaced it along cleavage cracks and in cross-cutting veinlets. In this replacement the lithiophilite has evidently exercised an orientating force on the reddingite since the latter comes to extinction simultaneously over a large section of the field under the microscope. The reddingite makes up perhaps ten per cent of the total mass of the lithiophilite specimen.

The following analysis of lithiophilite, by Gonyer, was made on about a gram of pure material, light brown in color. The deepness of the color seemingly is a good criterion for judging the amount of the triphylite admixture in the isomorphous series.

ANALYSIS OF LITHIOPHILITE

	PER CENT	MOLECULAR RATIOS
FeO	10.96	.1525
MnO	31.90	.4497
Na ₂ O	0.30	.0048
Li ₂ O	9.55	.3195
H ₂ O +	0.40	.0222
P ₂ O ₅	46.35	.3262
Insol.	0.16	
	99.62	Sp. gr.=3.481

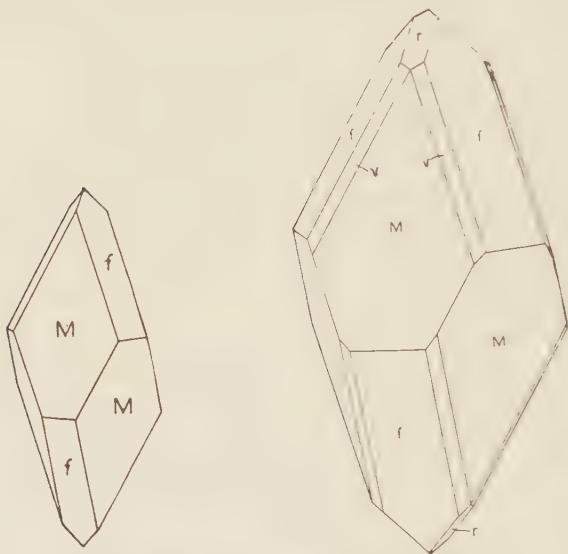
The ratio of $\text{Mn}:\text{Fe}=3:1$ in this lithiophilite is much like that of the Branchville material. The formula deduced from the analysis is $2(\text{Mn}, \text{Fe})\text{O} \cdot \text{Li}_2\text{O} \cdot \text{P}_2\text{O}_5$.

The optical properties were determined on material from the analyzed sample and are as follows:

$\text{Bx}(+)$, $2V=60^\circ \pm$. $\rho > v$ fairly strong

α and γ parallel to cleavages.

$\alpha=1.675$, $\beta=1.679$, $\gamma=1.688$.

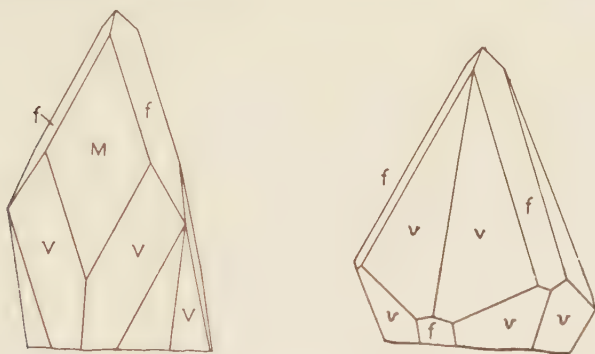


FIGS. 1 and 2. Rhodochrosite, Poland, Maine.

RHODOCHROSITE

The main mass of the rhodochrosite is a compact aggregate of rather small grains with an occasional cleavage piece a centimeter across imbedded in the small grains. Small crystals protrude into the cavities in the granular rhodochrosite. The crystals are etched, sometimes to the extent of obliterating the crystal outlines. The unit rhombohedron (r) is not etched whereas the rhombohedron (f) and the steeper form (M) always are. The scalenohedron (v) rarely present, is also unattacked. The various habits of the rhodochrosite crystals are illustrated in figures 1 to 4. Figure 1 is the dominant habit. The forms found on rhodochrosite from this locality are: $r(10\bar{1}1)$, $M(40\bar{4}1)$, $f(02\bar{2}1)$, $v(21\bar{3}1)$, $V(62\bar{8}1)$.

The optical properties of the rhodochrosite indicate that it is almost pure MnCO_3 .



FIGS. 3 and 4. Rhodochrosite, Poland, Maine.

QUARTZ

The quartz occurs as minute transparent doubly terminated crystals strung together to form tiny veinlets in the rhodochrosite. The two rhombohedrons are equally well developed, with no prism present.

EOSPHORITE

Eosphorite from this locality has been adequately described by Drugman⁴ who has discussed the composition, crystallography and optical properties. It is the only phosphate of the cavities which occurs as well formed unetched crystals. The crystals are, for the most part, embedded in the rhodochrosite but occasional prismatic crystals, well terminated, protrude into the cavities in the rhodochrosite. The general relations indicate that eosphorite is one of the earliest phosphates to form in the pockets.

REDDINGITE

This rare phosphate is found in two different associations at this locality. It replaces rhodochrosite as granular crystalline masses, and, as stated above it replaces lithiophilite. The mineral varies from almost colorless to a deep brownish red, the depth of color seemingly dependent on the degree of alteration of the material. In some cases the reddingite has been completely altered to a

⁴ *Loc. cit.*

mineral which is probably closely related to sicklerite which is here called landesite.

The material used for analysis was fairly light in color but not entirely free from altered grains.

ANALYSIS OF REDDINGITE

	PER CENT	MOLECULAR RATIOS	
Fe ₂ O ₃	0.95	.0059	
FeO	12.68	.1763	.7173 = 3 x .2391
MnO	38.36	.5410	
CaO	0.15	.0027	
Na ₂ O	trace		
K ₂ O	trace		
H ₂ O+	13.16	.7304	.7304 = 3 x .2435
P ₂ O ₅	34.52	.2429	.2429 = 1 x .2429
Insol.	0.45		
	100.27	Sp. gr. = 3.136	

The material analyzed yields the formula, 3(Mn, Fe)O.P₂O₅. 3H₂O with the ratio of Mn:Fe = 3:1, which is similar to the composition of the Branchville reddingite.

The optical properties are as follows:

Bx(+). 2V = 65° ±. $\rho > \nu$ perceptible.

$\alpha = 1.655$, $\beta = 1.662$, $\gamma = 1.683$.

There were no crystals found suitable for crystallographic measurements. The grains were usually bounded by contact faces with only an occasional crystal boundary.

DICKINSONITE

Dickinsonite is the rarest of the phosphates occurring here. It has been reported from one other locality, Branchville, Conn. The material is rather variable in color ranging from a dark brownish green to a yellowish green, suggesting common epidote at first sight. The crystals are small, tabular, and highly etched. Fairfieldite is nearly always associated with the dickinsonite and definitely later than the latter mineral. In some places there is a strong indication that the dickinsonite has been altered to fairfieldite probably by a leaching out of the alkalies and addition of lime. This alteration probably explains the rarity of dickinsonite. In this connection it is interesting to note that "a yellowish to olive green alteration product" is present in some of the fairfieldite at

Buckfield,⁵ according to Landes. This "alteration product" is probably residual fragments of dickinsonite.

The following analysis was made by Gonyer on half a gram of fairly pure material.

ANALYSIS OF DICKINSONITE

	PER CENT	MOLECULAR RATIOS
FeO	12.33	.1716
MnO	31.83	.4488
MgO	1.67	.0414
CaO	2.01	.0353
Na ₂ O	7.41	.1195
K ₂ O	1.73	.0184
Li ₂ O	0.20	.0067
H ₂ O	1.82	.1010
P ₂ O ₅	40.78	.2870
Insol.	1.00	
	100.78	Sp. gr.=3.266

The analysis of dickinsonite yields a formula similar to that of the Branchville type material. The formula is as follows: $7(\text{Mn, Fe})\text{O} \cdot 2(\text{Na}_2, \text{K}_2, \text{Ca})\text{O} \cdot 3\text{P}_2\text{O}_5 \cdot \text{H}_2\text{O}$; with CaO in relatively small amount as compared with the type material, and a correspondingly greater amount of the alkalis.

The optical properties are as follows: Bx(+), 2V near 90°. $\rho > v$ easily perceptible.

$$\alpha = 1.648 \pm .003,$$

$$\beta = 1.655 \pm .003,$$

$$\gamma = 1.662 \pm .003.$$

The indices of refraction vary somewhat in the various grains increasing with the depth of color of the mineral.

FAIRFIELDITE

Fairfieldite occurs as white foliated plates in rhodochrosite, and, in one specimen, as a pseudomorph after rhodochrosite. As stated above it also is found as a soft platy material on dickinsonite, probably as an alteration of the latter.

The following analysis was made on the freshest portions of the fairfieldite, by Gonyer:

⁵ Landes, K. K. *Loc. cit.*

ANALYSIS OF FAIRFIELDITE

	PER CENT	MOLECULAR RATIOS	
FeO	4.75	.0661	} 1 x .2750
MnO	14.82	.2098	
CaO	30.85	.5502	2 x .2751
Na ₂ O	0.41	.0066	
K ₂ O	none		
H ₂ O	9.70	.5384	2 x .2692
P ₂ O ₅	39.55	.2784	1 x .2784
Insol.	0.50		
	100.58	Sp. gr. = 3.016	

The analysis gives the usual formula for fairfieldite, that is $(\text{Mn,Fe})\text{O} \cdot 2\text{CaO} \cdot \text{P}_2\text{O}_5 \cdot 2\text{H}_2\text{O}$.

The fairfieldite from this locality has a ratio of Mn:Fe = 3:1 which seems to be the same for all the manganese-iron phosphates of the locality. The optical properties of Fairfieldite are difficult to determine by ordinary microscopic methods since the mineral is triclinic. By the use of the Fedorow stage, however, it becomes a comparatively simple operation to correctly determine the position of the optic planes with respect to the prominent cleavages. Figure 5 is a stereographic projection of the cleavages and the poles of the three major optic planes as found by the use of the Fedorow stage. The positions of the poles can then easily be expressed in terms of the coordinates using the well-known ϕ and ρ angles. The angle table for the optic elements of fairfieldite is here given using the method outlined below

	ϕ	ρ
<i>b</i> (010) best cleavage	0	90°00'
<i>a</i> (100) inferior cleavage	78°	"
X	-44°	56°
Y	+156°	36°
Z	+56°	79°

Figure 6 is a projection of the optical elements on the side pinacoid which is the cleavage upon which most grains lie under the microscope.

$$\text{Bx}(+). \quad 2V = 86^\circ \pm 1^\circ, \\ \alpha = 1.640; \beta = 1.650; \gamma = 1.660. \quad \text{All } \pm .002$$

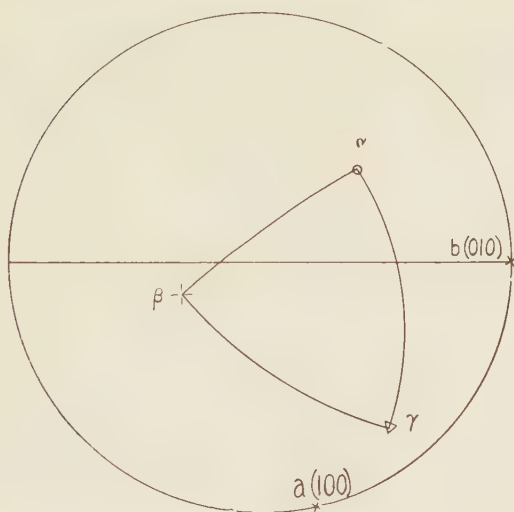


FIG. 5.

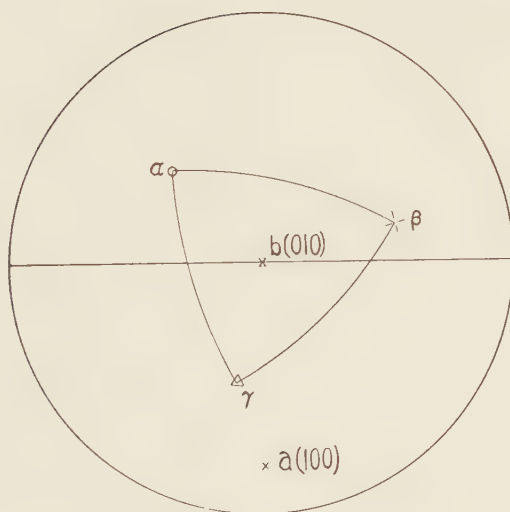


FIG. 6.

FIG. 5. Stereographic projection of the axes of the optical indicatrix. Projection on plane normal to c -axis. $\bigcirc = \alpha$; $- = \beta$; $\Delta = \gamma$; \times = pole of cleavage.

Fig. 6. Projection on best cleavage, $b(010)$.

APATITE

Apatite occurs as one of the latest of the phosphate minerals, resting on the rhodochrosite and occasionally on the other phosphates as small "nailhead" crystals, (Fig. 7.) slightly etched. Some

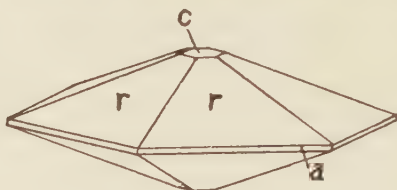


FIG. 7. Apatite, Poland, Maine.

specimens show apatite crystals of the normal habit, elongated parallel to the *c* axis. On these crystals the prism zone remains unattacked by the etching solutions while the pyramids are deeply etched.

LANDESITE A NEW MINERAL

The reddingite as stated above, has been altered to a brown mineral related to salmonsite. The crystals are rough, octahedral development suggesting in form the unit pyramid of reddingite. No adequate crystallographic data could be obtained on the rough crystals so that a close angular agreement between the supposed pseudomorph and reddingite could not be obtained. The crystals possess a good cleavage in the position of *b*(010) of reddingite and an inferior cleavage at right angles to the first. It is uncertain whether the first cleavage coincides with the cleavage position in reddingite.

ANALYSIS OF LANDESITE

PER CENT		MOL. RATIOS	
Fe ₂ O ₃	13.91*	.0869	= 3x.0290
Mn ₂ O ₃	2.69		
MnO	33.65	.5763	= 20x.0288
MgO	3.07		
CaO	1.39		
H ₂ O	13.60	.7556	= 27x.0280
P ₂ O ₅	31.94	.2248	= 8x.0281
Insol.	0.13		
100.38		Sp. gr.=3.026	

* Fe₂O₃+FeO, (FeO not determined).

Material for analysis was carefully picked but it was found impractical to get it entirely free of impurities since there was not much available. The above analysis was made by Gonyer on a gram sample.

This analysis yields the formula $3\text{Fe}_2\text{O}_3 \cdot 20\text{MnO} \cdot 8\text{P}_2\text{O}_5 \cdot 27\text{H}_2\text{O}$, which comes closest to salmonsite, described by Schaller, from Pala, as an oxidation and hydration product of hureaulite. The optical properties, however, indicate that the mineral is very different. It was at first supposed that this alteration of reddingite was closely related to sicklerite, another alteration product, from Pala, since the optical properties of the two are quite similar. The chemical analyses of the two are, however, different. This mineral seems to represent a new species for which the name landesite is here proposed in honor of Professor Kenneth K. Landes who has done much work on the pegmatites of Maine.

The optical properties of the analyzed material are as follows:

Bx (-). 2 V large. Z \perp to best cleavage and X \perp to an inferior cleavage. Pleochroism, X = dark brown, Y = light brown, Z = yellow. $\alpha = 1.720$, $\beta = 1.728$, $\gamma = 1.735$. It is interesting to note, in connection with this occurrence that Landes⁶ has also reported an oxidation product which he believes related to sicklerite.

CASSITERITE

This mineral has been found in the study series on only one specimen. There are residual fragments of rhodochrosite within it but some veinlets of the carbonate seem to cut it also so that the two are probably nearly contemporaneous. The material was identified optically from the following data:

Uniaxial (+), $\omega = 2.01$ = light green; ϵ = brown.

The strong pleochroism of the cassiterite is worthy of note since that property is rarely mentioned in the literature for this mineral.

BERYL

A single large, bluish white crystal of beryl from this locality is in the Harvard Collections. Although it is not a part of the phosphate suite of minerals, with which this paper is mainly concerned, it merits description because of the excellent etch figure developed on the base. The crystal has been eaten away in greater part by the

⁶ Landes, K. K. *Loc. cit.*

etch solutions, the base, however, is still present and deeply pitted by negative solution crystals. These etch faces forming the negative crystals are of the simple forms $p(10\bar{1}1)$ and $s(11\bar{2}1)$, and give excellent reflections. This is somewhat unusual since etch forms usually have a complex relationship to the crystal axes. The forms developed on the prism and pyramid s are too curved to measure, their general character only being indicated in fig. (8).

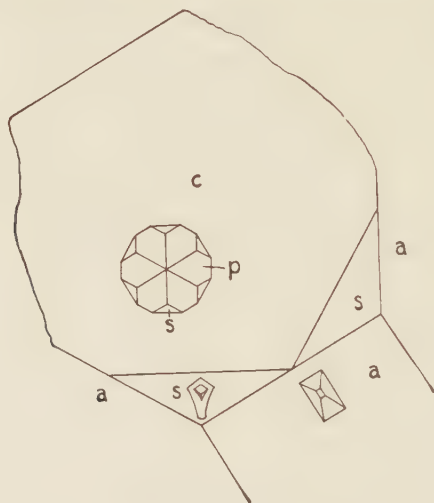


FIG. 8. Etched Beryl, Poland, Maine.

The index of refraction ($\omega=1.585$) indicates that this beryl is rather high in alkalis and probably contains caesium. Landes places this type of beryl in the second phase, the hydrothermal phase, of his classification so that it is probably earlier than the above mentioned phosphates.

CONCLUSION

From the foregoing description of the minerals and their probable sequence, it is seen that the solutions leading to their formation were essentially of manganese phosphate with carbonate and water, lithia-rich in their earlier phase and calcium rich toward the end of the deposition. These same conditions were presumably present at Buckfield, Maine, Newry, Maine, and Branchville, Conn., since the same minerals were formed in essentially the same general

sequence. This remarkable similarity of four localities at which lithia-pegmatites have been studied seems to require a closed system, with no ingress of new material into the pegmatite solutions.

The authors are greatly indebted to Professor Palache for suggesting this study and for critically examining the manuscript.

A NEW IRON METEORITE FROM CARBO, MEXICO

CHARLES PALACHE AND F. A. GONYER, *Harvard University*.

In 1928 the Mineralogical Museum of Harvard University purchased from H. W. Kelsey of Nogales, Arizona, an iron meteorite concerning which Mr. Kelsey supplied the following data.

"The meteorite was found in 1923 by Mexican cowboys while riding the range on the Alamo Ranch about 40 miles west of Carbo, Sonora, Mexico. It was shipped to Nogales after its meteoritic character had been established by a mining engineer and there it remained until shipped to Cambridge in 1928."

The region in which the meteorite was found is sparsely settled with few towns. On a detailed map of the State of Sonora however, the Alamo Ranch is indicated lying in lat. $29^{\circ} 40' N.$ and long. $111^{\circ} 30' W.$, about 5 miles north of the tiny village Bacuache. The nearest place shown on most maps of Sonora is Carbo, a station on the Southern Pacific Railway of Mexico, Alamo Ranch being about 40 miles to the westward. Accordingly the iron will be designated as the Carbo meteorite.

The mass weighed about one thousand pounds but its exact weight was unfortunately not determined. It was intact, showing only a small fracture surface where a few ounces of iron had been removed with chisel and hammer. The fracture showed clearly the presence of a coarse octahedral cleavage. The mass is wholly covered with a smooth coating of rust. When received it was in many places encrusted with a limey coating, easily removed with dilute acid. It is roughly tetrahedral in shape the triangular base (plate 1) measuring about 37 cm. (15 inches) on a side, the broadest face from this base to the rounded wedge-shape opposite end (side view, plate 2) about 80×45 cm. (32×18 inches).

The surface is covered with rounded depressions of the kind commonly observed on meteoric irons, well shown in plate 2. There are in addition ten or more cylindrical holes clearly shown in plate 1 which are roughly parallel in direction. The largest is 7 cm. deep with a diameter of 1.5 cm. They are as regular in form as though produced by a drill. It is highly probable that these cylindrical holes were originally filled with troilite but none is now left in any of them.

In the hope of intersecting some of these cavities within the meteorite, the end of the mass was sawed off approximately paral-



PLATE 1. Iron Meteorite from Carbo, Mexico.

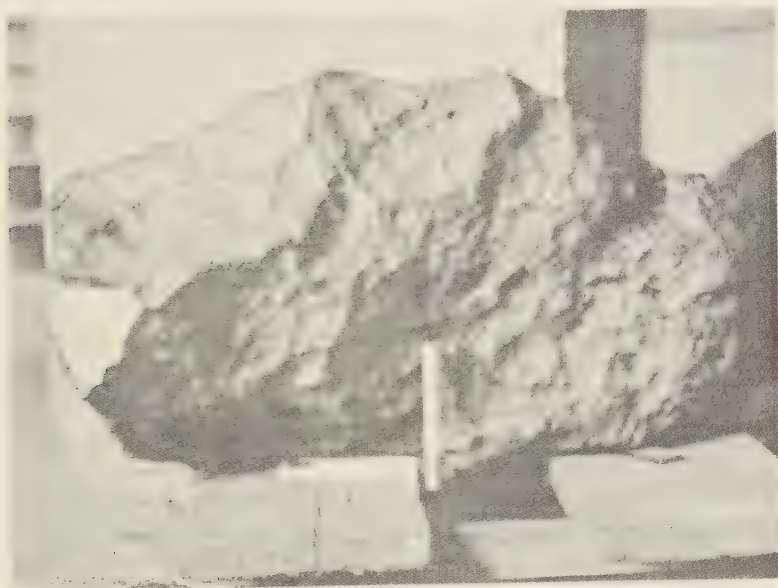


PLATE 2. Iron Meteorite from Carbo, Mexico.

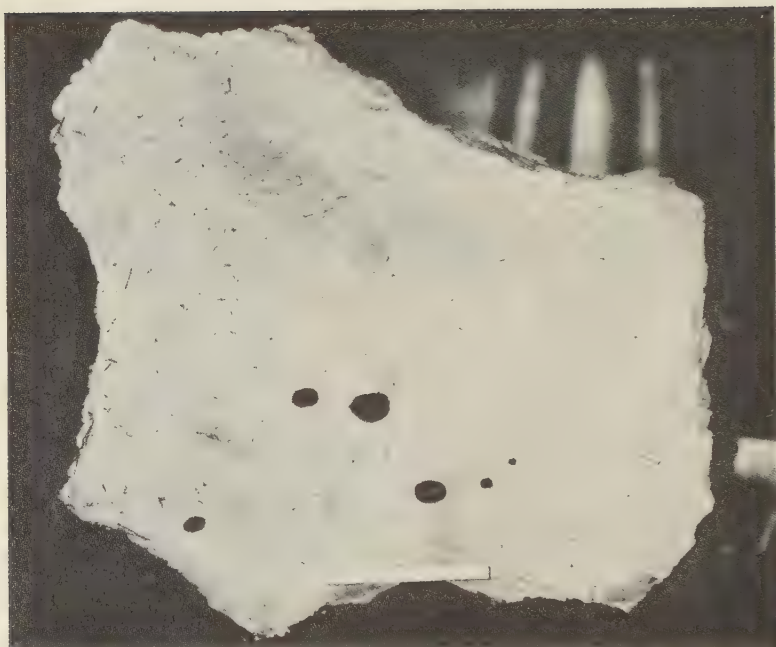


PLATE 3. Iron Meteorite from Carbo, Mexico.

lel to the triangular base and a slab about 2 inches thick was cut from this end piece. Numerous nodules of troilite were intersected on one of these cuts but none of them extended through the slab to the second cut. Their circular section is well shown on plate 3 but no proof was secured as to their pencil-like form. Their dimensions in cross-section are, however, in harmony with the idea that the holes are moulds of troilite masses.

The photograph of the etched section of the Carbo Meteorite (plate 3) exhibits clearly its well marked octahedral structure. The bands of kamacite are regular and have an average thickness of from .5 to 1 mm. It may therefore be classified as a medium octahedrite. The taenite bands are very narrow and fairly continuous.

The plessite filling the interspaces of the kamacite bands is for the most part finely banded giving to each grain in certain lights a satiny sheen.

Reichenbach lamellae of schreibersite up to 3 cm. in length cut across the structure as may be seen in the photograph. Each has on either side a band of kamacite. The troilite nodules are 2 cm. in diameter or less and do not disturb the octahedral structure. Each is bordered by a thin layer of schreibersite.

A sample of the iron free from visible troilite particles was analyzed by the junior author with the following result:

	PER CENT
Fe	90.64
Ni	8.68
Co	0.36
P	0.16
S	0.03
Insol.	0.04
Cu	trace
Mn	absent
	<hr/>
	99.91

This analysis is in close agreement with that of the normal octahedral iron and shows no points of special interest.

SCORODITE FROM GOLD HILL, TOOLE CO., UTAH

WILLIAM F. FOSHAG,¹ *U. S. National Museum,*
HARRY BERMAN, *Harvard University,* and
RUTH ALLEN DOGGETT, *Radcliffe College.*

The determination of the optical properties of scorodite by E. S. Larsen² has suggested that there are at least two minerals included under the name scorodite. One, with medium high indices of refraction, is the more common; the other although similar in general appearance and crystal form, has indices of refraction considerably higher (Kaira, Bungo, Japan). Unfortunately there is not sufficient material on the specimens of the latter type for a satisfactory chemical analysis but of the more normal scorodite there is abundant material available from the arsenic deposits of Gold Hill, Toole County, Utah.

The scorodite from this locality forms bodies of considerable magnitude as an alteration product of arsenopyrite and was present in sufficient quantity to form a valuable ore for the manufacture of calcium arsenate. The scorodite is, for the most part, fine granular to compact and usually more or less siliceous, but an occasional nest of small crystals was met with. These crystals are satisfactory material for an examination of this type of scorodite.

Chemical analysis of these crystals shows the mineral to be normal scorodite, essentially free of isomorphous admixture of other mineral molecules. The sample analyzed consists of grayish green crystals, averaging 1 mm. in size. These crystals, while glassy, were clouded by numerous fine cracks and occluded occasional small specks of extraneous material. The analytical results are given below.

The crystals, averaging about 1 mm. in size, while sharply formed, were not satisfactory for crystal measurement. The faces in all cases were too curved for good reflections. The following values obtained on one of the best crystals, show its essential similarity to normal scorodite.

FORM	ϕ	ρ	CHARACTER
<i>a</i> (100)	90°00'	90°00'	medium size, poor reflection
<i>n</i> (110)	54 34	90 00	small to medium, poor
<i>p</i> (111)	48 45	56 24	large, poor

The crystals are orthorhombic and nearly octahedral in habit.

¹ Published with the permission of the Secretary of the Smithsonian Institution.

² Microscopic Determination of the Nonopaque Minerals. *U. S. Geological Survey, Bull.* 679, pp. 132-133, 1921.

ANALYSIS OF SCORODITE, GOLD HILL, UTAH. (U. S. N. M. 94821)

William F. Foshag, *analyst*.

	1.	2.	3.
Insoluble	0.42		
Ferric oxide (Fe_2O_3)	34.13	34.3	34.6
Alumina (Al_2O_3)	none		
Ferrous oxide (FeO)	0.84		
Lime (CaO)	0.38		
Magnesia (MgO)	0.01		
Arsenic pentoxide (As_2O_5)	48.42	49.4	49.8
Phosphoric pentoxide (P_2O_5)	none		
Water (+)	15.73	16.0	15.6
Water (—)	0.23		
Specific Gravity 3.413.	100.16		

1. Analysis of sample
2. Analysis after deducting extraneous material
3. Theoretical analysis for $\text{Fe}_2\text{O}_3 \cdot \text{As}_2\text{O}_5 \cdot 4\text{H}_2\text{O}$.

The color of the scorodite is pea-green³ in crystals, but is somewhat lighter in the more massive specimens. The mineral is optically negative, $2V = 54^\circ \pm 5^\circ$. $\rho > v$ (easily perceived in the interference figure but not sufficiently strong to measure on the Fedorow stage.) The indices of refraction for yellow light as determined by the Merwin dispersion method, are as follows: $\alpha = 1.784 \pm .001$, $\beta = 1.796 \pm .002$, $\gamma = 1.814 \pm .001$. Dispersion $F-C = .03 \pm .005$.

In all respects the mineral from Gold Hill is a normal scorodite and the data given here characterize this type of material satisfactorily. The abnormal scorodites will be investigated if sufficient material can be obtained for satisfactory analyses.

³ Ridgeway, Robert. Color Standards and Color Nomenclature, *Washington*, 1912, Pl. XLVII.

